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FOURTH SERIES.

VOL. XV—[WHOLE NUMBER, CLXV.]

No. 87.—MARCH, 1903.

NEW HAVEN, CONNECTICUT.

1903.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 125 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XV.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

PART II. PRIMATES.

INTRODUCTION.

SOMEWHAT contrary to the accepted order of arrangement usually adopted in treating of the Mammalia, I select next for consideration the Primates, a perfectly natural and homogeneous order, including the Lemurs, Monkeys, and Apes, as well as Man himself. This latter fact invests the study with more than ordinary importance, inasmuch as any additional evidence bearing upon the past history of the group to which man belongs cannot fail to prove of the highest interest, even though it throw only a side light upon the development of the human kind. In view of the belief that the general current of opinion seems to be setting strongly in the direction of the conclusion that the ancestry of the human species, with all its endowments, both mental and physical, must be sooner or later traced with certainty to this source of origin, we may be pardoned for a somewhat exhaustive presentation of the facts which our fossils exhibit.

The various groups of Mammalia have been developed and specialized along diverse lines, the primary cause of which we may regard as having been due to adjustment to varying conditions of environment. It thus happens that different sets of organs have been involved in these changes, so that when we attempt the classification and definition of a natural group, we seek to learn what structures have been most profoundly affected. In the case of the Primates, the enlargement and specialization of the cerebral lobes of the brain constitute the

character *par excellence* in which they have made the greatest progress and in which their evolution has been most marked. The very early development of prehensile hands and feet and the better arrangement of the cerebral circulation have been intimately associated with this progress and are therefore factors of prime taxonomic value and importance. In other words, the Primates have adapted themselves more widely to environment than any other mammalian group, in consequence of which they present well-defined skeletal indices or equivalents, so that whenever they are sufficiently preserved, it is possible to recognize them with a degree of certainty not usually found in other groups of the Mammalia.

Characters of the Cerebral Circulation.

As regards the first set of these characters (the enlargement of the brain), like all other specialized features which come to distinguish a group or order in the final or advanced stages of its evolution, they are of necessity less distinctly marked in the earlier representatives than in the later ones; so that, as we approach the point of origin, greater and greater difficulties are experienced in the application of such characters as a real test of affinity. Thus it is that we find in the less specialized members of the Primates, such as the lemurs and the oldest true monkeys, the relative development of the cerebral hemispheres to be little, if any, greater than that of many of the Insectivora; and were we compelled to depend upon this character alone, it would be in many instances practically impossible to determine whether the animal in question were a Primate or an Insectivore.

Fully recognizing the importance of thus clearly distinguishing between these small-brained Primates and other contiguous groups, in the matter of certain cranial characters, I have been led to make a careful and somewhat exhaustive study of the manner in which the blood supply is furnished to the cerebral hemispheres. Especial attention to this subject has been given, on the assumption that it must have been not only intimately associated with the progressive enlargement of the cerebral hemispheres in the Primates, but was in a way not now clearly understood, in some degree at least, responsible for it. If it is true that certain fundamental differences of this character exist between the several orders, the practical advantage to the paleontologist will be great, since it is only on very rare occasions that he has to deal with complete skeletons of the extinct species. In order to bring out these characters more clearly, I shall first consider the Insectivora, and I begin by quoting Huxley's statement of the course of the entocarotid in the hedge-

hog, figure 100. He says:* "The course of the internal carotid artery is remarkable. When it reaches the base of the skull it enters the tympanum and there divides into two branches, of which one traverses the stapes, and, passing forward in a groove of the roof of the tympanum, enters the skull and gives rise to the middle meningeal and ophthalmic

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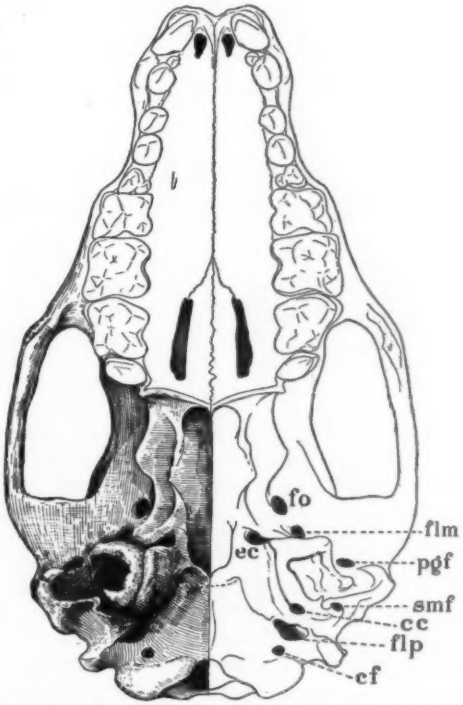

FIGURE 100.—Enlarged view of the base of the skull of *Erinaceus europæus*; showing the foramina.

fo, foramen ovale; *flm*, foramen lacerum medium; *ec*, eustachian canal; *pgf*, postglenoid foramen; *smf*, stylomastoid foramen; *cc*, carotid canal; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

arteries. The other branch passes over the cochlea, enters the skull by a narrow canal near the *sella turcica*, and unites with the circle of Willis."

This course and distribution of the entocarotid is not only characteristic of the hedgehog, but is also found in the follow-

* Anatomy of Vertebrated Animals, 1872, p. 380.

ing additional genera of the Insectivora: viz., *Gymnura*, *Tupaia*, *Talpa*, *Scalops*, *Condylura*, *Sorex*, *Myogale*, *Centetes*, *Hemicentetes*, *Ericulus*, *Solenodon*, *Chrysochloris*, *Leptictis*, and *Ictops*. This list, it will be seen, includes typical representatives of all living families except the Macroscelidæ and Potamogalidæ. I have not been able to examine the skulls of any members of these two families, but I have very little doubt that it is true of them also, and that this course of

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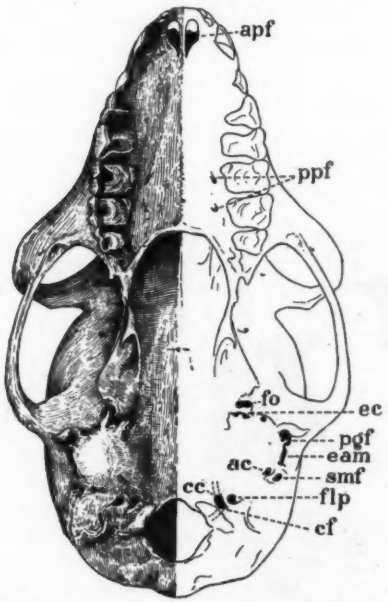

FIGURE 101.—View of the base of the skull of *Lemur catta*.

apf, anterior palatine foramen; *ppf*, posterior palatine foramina; *fo*, foramen ovale; *ec*, eustachian canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *ac*, accessory carotid canal; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cc*, carotid canal; *cf*, condyloid foramen.

the artery is a constant and important diagnostic feature of the Insectivore skull. It is of interest to note that in *Galeopithecus* the course of the artery is not like that in other Insectivora, but agrees with that of the bats and one important group of the lemurs. It may be also added that this course of the artery, according to Owen,* is true of some, if not all, Rodentia. The practical application of this knowledge of the course of the entocarotid, to the classification of certain fossil

* Anatomy of Vertebrates, 1868, vol. iii, p. 229.

forms of supposed Insectivora, is thus rendered possible by the distinct grooves which both branches make in the under side of the petrosal. In the case of all the recent forms which I have examined, as well as of some of the well-known fossil types, the direction of the two branches can be determined with ease.

Turning next to Primates, we find that in certain of the lemurs, notably the Indrisinæ and Lemurinæ, the main branch of the entocarotid artery enters the cranial cavity through a canal at the postero-internal junction of the tympanic bulla and the basioccipital, near the point of exit of the condyloid foramen, figure 101. The main artery passes forward and into the cranial chamber at the side of the *medulla*, wholly within the posterior or cerebellar fossa. In some species of these two subfamilies, there is a small canal entering the bulla in the position corresponding to the foramen for the entocarotid in the Insectivora; this is undoubtedly the homologue of the entocarotid in that group, but it is small and inconsiderable, and appears to be practically absent in all except *Lemur* and *Propithecus*. In these two genera, especially the latter, the tympanic branch is nearly as large as the main artery.

In the remaining species of the living Lemuroidea, there is no canal for the entocarotid in the position above described for *Lemur* and *Propithecus*, but there is a large and conspicuous *foramen lacerum medium*, which has its usual position at the antero-internal angle of the petro-tympanic, figure 102. Mivart constantly spoke of this foramen as the carotid canal, and from certain distinctive evidences of an arterial vessel entering the cranial cavity in this situation, in many imperfectly prepared skulls of these species which I have examined, there can be apparently no doubt that the office of this foramen is the transmission of the main entocarotid artery. It will be thus seen that there are two distinct types of entocarotid circulation in the Lemuroidea, both of which are sufficiently distinct from the Insectivora to afford reliable diagnostic characters.

In the remaining Primates or Anthropoidea, including *Tarsius*, the entocarotid circulation presents another arrangement. In this group, the course of the artery corresponds more nearly with that of the Insectivora, in that its canal traverses the petro-tympanic chamber. There is an important difference in the two, however, for in the Anthropoidea the stapedial branch of the artery is wholly wanting. The canal pierces the bulla in its posterior moiety, and passing forward over the cochlea, enters the cranial chamber in the middle or cerebral fossa, near the posterior clinoid process, just in advance of the tentorial ridge. This is evidently a superior

arrangement to that seen in *Lemur* and *Propithecus*, for the reason that the blood is delivered more directly to that part of the brain which it is intended to supply.

The following variations in the position of the external opening of the canal may be noted: In *Tarsius*, figure 103, it is placed a little anterior to the external auditory meatus and

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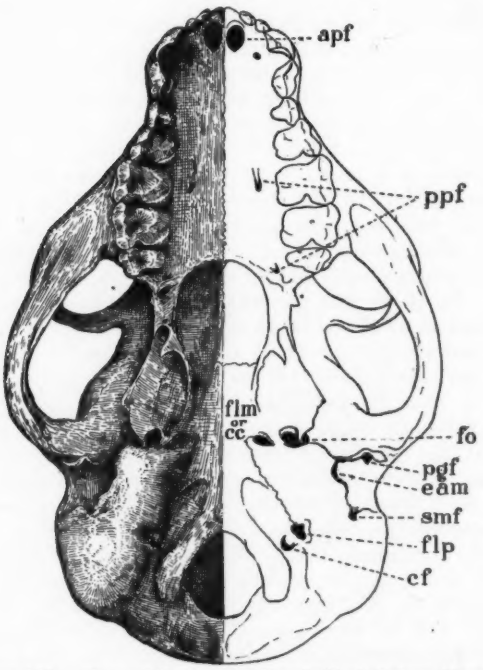

FIGURE 102.—View of the base of the skull of *Galago Monteiri*.

apf, anterior palatine foramen; *ppf*, posterior palatine foramina; *fo*, foramen ovale; *flm* or *cc*, foramen lacerum medium or carotid canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

rather to the outer than to the inner side of the bulla; in *Hapale* it is opposite the middle of the external auditory meatus upon the inner side of the bulla; in the Cebidæ, figure 104, it is yet more internal and somewhat more posterior;* and

*In *Hapale* and *Nyctipithecus* an interesting variation occurs. The main artery pierces the bulla in its usual position, but it apparently gives off a considerable branch, which enters the cranial chamber through a canal between the bulla and the basioccipital. This results in an arrangement similar to that found in *Lemur* and *Propithecus*, except that the position of the main branch is reversed.

in the Old World monkeys and the Anthropoids it has practically the same position as in the human species. In the extinct Eocene apes, as far as known, the main canal pierces the bulla in its posterior external portions. It should be here noted, also, that the relative size of the canal steadily increases from the small-brained to the large-brained forms, and that

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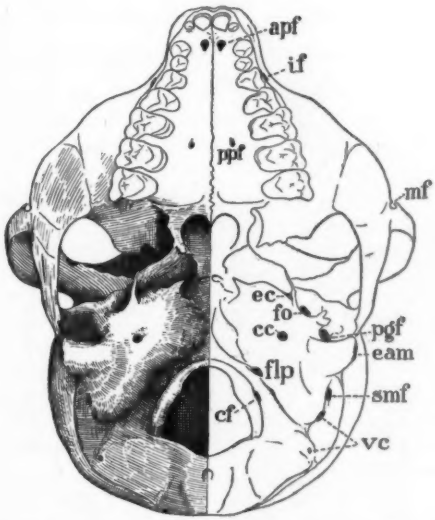

FIGURE 103.—Basal view of the skull of *Tarsius spectrum;* enlarged.

apf, anterior palatine foramen; *if*, infraorbital foramen; *ppf*, posterior palatine foramen; *mf*, malar foramen; *ec*, eustachian canal; *fo*, foramen ovale; *cc*, carotid canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *smf*, stylomastoid foramen; *vc*, venous canals; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

this increase is directly proportioned to the degree of development of the cerebral hemispheres.

There yet remain to be described other characters of the blood supply to the brain through the vertebral arteries, in certain groups of the Primates, which are of importance from the standpoint of classification. In the lemurs,* the New World, and a few of the Old World monkeys, the course of the artery through the transverse process of the atlas is somewhat different from that seen in *Tarsius*, the anthropoid apes, and man. If the atlas of an anthropoid ape or man is viewed from behind, the large vertebrarterial canal will be

*The only exception which I have been able to find in this group is *Perodicticus potto*, in which the anterior bony bridge is not quite complete.

seen perforating the transverse process at its junction with the lateral mass of the bone. The anterior continuation of this canal is a deep groove turning sharply upward to reach a second perforation or deep notch in the anterior edge of the superior arch, at the upper extremity of the oval cup-shaped cotylus. This latter notch or foramen is known as the *sinus atlantis*, and serves for the entrance of the vertebral artery

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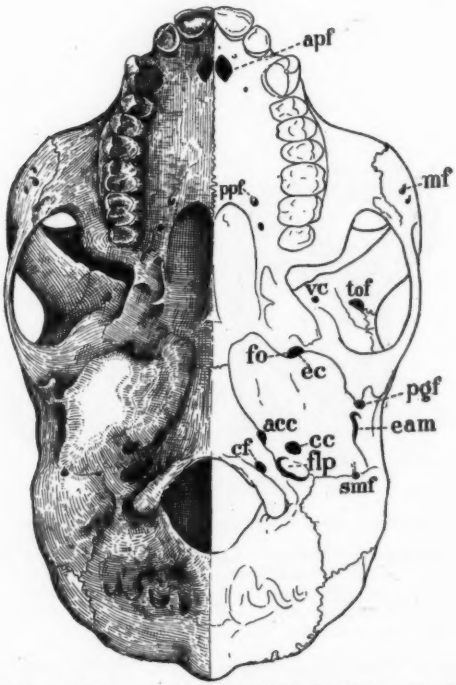


FIGURE 104.—Basal view of the skull of *Nyctipithecus felinus*.

apf, anterior palatine foramen: *ppf*, posterior palatine foramen; *mf*, malar foramen; *vc*, venous canal; *tof*, temporo-orbital foramen; *fo*, foramen ovale; *ec*, eustachian canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *acc*, accessory carotid canal; *cc*, carotid canal; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

and the exit of the first spinal or suboccipital nerve. Now, in the lemurs and lower monkeys, a strong bony bridge is thrown forward from the transverse process to the upper extremity of the cotylus, so as to cover in that part of the canal or groove where it turns sharply upward, and give separate openings for the superior and inferior (anterior and posterior of anthro-

potomy) divisions of the suboccipital nerve. This difference in the arrangement of the canal is constant and well marked, and serves as a reliable guide for distinguishing certain of the groups. The latter condition is also found in the Insectivora, and may be therefore looked upon as the more primitive of the two.

Finally, I may mention the absence of a separate opening *(foramen spinosum)*, for the entrance of the middle meningeal artery into the cranial cavity, in all Primates except man.

Characters of the Prehensile Extremities.

The second set or group of characters of fundamental importance, by means of which the Primates are distinguished from all other orders of the Mammalia, relates to the modification of the hands and feet into more or less perfect prehensile or grasping organs, and in this respect they stand sharply apart from all other divisions of Eutherian mammals. Of the causes which led to this modification, very little is known, but there can be hardly any doubt that it was one of the primary distinguishing features of their remote Metatherian ancestors far back in the Mesozoic, and that its appearance constituted one of the first steps which led to their subsequent differentiation into such a distinct group. The particular type of extremity from which the prehensile modification arose was undoubtedly that of the plain plantigrade condition; and the assumption of an arboreal manner of life, we may readily believe, was the all-important determining factor in its evolution.

Exclusive of man, the Primates are, without exception, the most preëminently arboreal in habit of all the Mammalia. The arrangement of the thumb and great toe in opposition to the other digits, thus making it possible to take a firm hold or grasp upon the branches of a tree, is one of vast superiority to that in which the digits depend for their effectiveness upon sharp claws.

In the latter case, the claws serve as so many hooks by means of which the weight of the body is sustained in the act of climbing, whereas in the prehensile hand or foot of the Primates the hold is rendered effective by the opposability of certain of the digits to each other. The advantage of the grasping extremity over that which is solely dependent upon the hooked claws is seen in the ability of the animal possessing the former to traverse the forest without descending to the ground. Where the large branches of the adjoining trees interlace, the clawed animal experiences little difficulty in passing from one to the other, but if the trees are scattering, so that only the small branches touch, his progress is barred. To the animal with prehensile extremities, however, the case

is different; he simply runs out until he can gather a handful of smaller branches of the opposite tree, and swings himself across the interval with ease. Indeed, the skill displayed by monkeys in climbing surpasses that of any other animal.

It is of course not now possible to discover just what combination of circumstances first led the ancestors of the Primates to adopt an arboreal habit; it may have been for the purpose of greater protection from enemies, it may be that certain kinds of food, such as fruit and nuts, attracted them to the trees, or it may have been both; but, whatever the cause, it appears certain that this manner of life was adopted very early in their career, and has been responsible for one of the most important structural modifications which they now exhibit.

Another matter of great interest in connection with the prehensile extremities relates to their probable influence upon the growth of the cerebral hemispheres, as well as the general increase in intelligence in the Primates. No very complete phyletic history can as yet be made out for any existing species of monkeys, but such evidence as is obtainable demonstrates very clearly that the brain has increased in size over and above that found in the earliest forms. In some instances, this increase has been less marked than in others, but there has been, nevertheless, a gradual development of the cerebral hemispheres in all groups of the Primates. In the case of the lemurs the increase has been comparatively small, while in the apes and monkeys it has been relatively great.

Now, to what causes is it possible to attribute this development of the brain? A few modern naturalists of note claim to have discovered evidence of an internal perfecting or directing principle, by means of which variations along a given line only are originated and preserved, and which, through the subsequent action of natural selection, forever holds them steadfast in the narrow path of their final development. In any such view of evolution, I find it necessary to express my utter and unqualified disbelief. In my judgment, not only is there no evidence in support of such a proposition, but, on the contrary, all the facts of paleontology, as far as they are capable of any interpretation, point directly to an opposite conclusion. Such a view of evolution, moreover, presents no advantages over the antiquated doctrine of special creation, which, on account of its inconceivability as well as of total lack of evidence in its support, has long since been relegated to the category of extinct ideas.

In like manner do I find it equally difficult, and inconsistent with the evidence, to believe in the all-sufficiency of natural selection, as advocated by the Neo-Darwinian school of evolutionists. If we had no evidence other than that afforded by the well-known modifications in structure of the cave faunæ

upon which to rest our belief in certain factors concerned in evolution, we could yet feel reasonably assured that the inherited effects of disuse had played no unimportant part in the retrogressive changes which these animals have suffered in the past.

According to the very able researches of Packard and Eigenmann, the loss of sight as well as other important changes in these cave forms can be explained on no other rational hypothesis than that of *the inherited effects of disuse;* and while the admission of such explanation, as a fact, may render impossible the construction of a satisfactory theory of heredity, in the light of our present knowledge, then all that can be said is, so much the worse for a theory of heredity.* If, therefore, the inherited effects of disuse are capable of producing such profound modifications as those to which reference has just been made, it follows that the inherited effects of prolonged *use* must have been equally potent in the production of change in animal structure. This, I may say, is the kind of evolution that was taught by the great master minds who gave it birth, and, notwithstanding all the subsequent discussion which has taken place regarding the factors concerned in the process, I am still firmly of the opinion that the theory of evolution, as set forth by Darwin and Huxley, comes nearer to the truth than all others yet advanced.

With this understanding of the nature of the causes by means of which we must, in my judgment, seek to explain the progressive changes in brain structure among the Primates, we are now prepared to return to the inquiry.

It is first necessary to recall that different species of animals seem to employ the special senses in different degrees, for the purpose of acquiring information of any object that may excite their attention. Among such animals as our domestic horse and cow, if confronted by any object new or strange to them, they will at once give evidence of the fact by every attitude of marked attention. If not sufficiently frightened to run away, they proceed to inspect it from every point of vantage. Sight alone, however, seems to be insufficient to satisfy their curiosity or allay their suspicions, and it is not until they are able to approach near enough to test it fully by the sense of smell that they seem to be able to acquire the necessary information they desire. This same characteristic of depending largely upon the sense of smell is true of many animals in a state of nature. It is quite as much by this means as by the sense of sight that they detect danger.

As among the hoofed animals, the Carnivora also depend largely upon sight and smell for information. In rare instances, the dog will use his paw for the purpose of turning an object

* For the evidence in favor of the transmission of acquired characters, see also the works of Hyatt, Ryder, Cope, Beecher, and others.

over, so that he may inspect it more closely, and the raccoon and bear do this more frequently, but the lack of opposability of the thumb places great difficulties in the way of handling an object to any considerable extent.

Among the monkeys, on the other hand, information of a strange or suspicious object is obtained by sight, at first always at a respectful distance. If the animal is assured that no imminent danger threatens, he will cautiously approach for closer scrutiny; if harmless, he soon takes the object in his hands and inspects it carefully upon all sides. If there is any internal mechanism to excite curiosity, it is forthwith pulled in pieces or broken, in order that every part may be examined attentively. It is only in case of an article of food that he uses his sense of smell. In this extensive use of the hands, the monkey exhibits traits and capabilities for the acquisition of knowledge far in advance of all other mammals. Not only is there great curiosity, but an active desire for information of all things new or strange in his surroundings. The undisputed testimony of many excellent observers could be quoted in support of this assertion, but the facts are so well known that it is scarcely necessary.

That which interests us most in this connection is the extent to which the animal makes use of the prehensile extremities in acquiring information and satisfying curiosity. There can be little doubt that, as in man, the sense of sight is the source from which the greatest amount of information is derived; but at the same time the ability to pick up, handle, and closely inspect any object,—possible only with prehensile extremities,—has constituted a most powerful aid in acquiring knowledge of the smaller details. The constant action and reaction of this process, with its inherited effects, upon the brain, throughout innumerable generations, we may readily believe, have resulted in an ever widening circle of psychic activity and cerebral development.

Another factor which may have had its share in the process is the particular way in which the brain has received its supply of blood from the heart. As we have already seen, the arrangement of the entocarotid circulation is different in monkeys, apes, and man, from that found in the lemurs. In one group of the lemurs, the blood through the entocarotid is carried directly to the base of the skull, where the artery enters the middle or cerebral chamber. In another group, the blood is delivered into the posterior chamber of the skull through a foramen alongside the otic bulla, or ear pouch. In monkeys and man, the entocarotid pierces the petro-tympanic, and delivers the blood directly to the base of the brain in the middle chamber. As far as directness of supply is concerned, the

arrangement found in one section of lemurs appears to be as advantageous as that of monkeys and man, and upon any hypothesis which involves this blood supply through the entocarotids, the brain of these forms of lemur should have developed as rapidly as that of the monkeys.

The explanation of this seeming inconsistency, I apprehend, is to be found in the relative importance of the two sets of arterial feeders of the cerebral hemispheres; viz., the entocarotids and vertebrals. The latter, it should be remembered, lie deeply in the neck and pursue a somewhat tortuous course through the foramina of the neck vertebræ, finally uniting on the floor of the posterior chamber of the skull to form the basilar artery. From this trunk, a pair of arteries is given off, which diverge and pass forward along the floor of the middle chamber, to unite with the entocarotid branches, forming, in conjunction with an anterior connecting branch, the circle of Willis. From the union of the entocarotid with the anterior branch of the basilar springs a large artery which passes upward through the fissure of Sylvius, and gives the principal supply of blood to the cerebrum.

In monkeys and man, the vertebral branches are relatively small and insignificant, and the entocarotids correspondingly large. In the lemurs, on the other hand, this condition is reversed; the vertebrals are large and the entocarotids small. In the one case, the entocarotids became the predominant feeders of the cerebral hemispheres, and there was corresponding increase in size and a general increase in intelligence; in the other, this office was performed largely by the vertebrals, and the brain developed more slowly. It is evident that the advantage lay on the side of the more direct current, which must have resulted in giving a greater stimulus to the psychic activities of the monkey, and have been responsible for his evolution in this direction.

Having now stated the probable relationship which must have existed almost from the very beginning between the development of the cerebral hemispheres, the prehensile extremities, and the carotid circulation, I proceed next to an examination of the skeletal structure of the manus and pes, in which the osseus index of some of these conditions above described is plainly exhibited. Selecting one of the more typical representatives of the order, the chief osteological characters of the hand and foot may be briefly stated as follows:

The Pes.—When the four outer digits are made to rest upon a plane surface, the tibial facet of the astragalus looks almost directly inward, while the fibular facet looks upward and a little outward.* The head of the astragalus is obliquely

*These two characters do not apply to the human foot, which has been modified for terrestrial progression in the erect position.

placed and is much rounded; the tuber of the calcaneum is short and incurved; the cuboid is high, broad from side to side, and of comparatively little dorso-palmar thickness; there are never less than five digits, and with the exception of the marmosets and man, the hallux is always opposable; the metatarsals are slightly interlocking, and their distal extremities, exclusive of the hallux, display a characteristic pattern, compressed from side to side, much rounded from before backward, and with progressive disappearance of keels, grooves, and sesamoids of the flexor tendons; the phalanges are elongate and curved, and the unguals are in various stages of transition from claw to nail; the distal extremity of the metatarsal of the hallux is always provided with sesamoids, and has a distinct keel and grooves; its opposability is shown by its deeply excavated proximal extremity and the convex surface of the internal cuneiform, and its terminal phalanx is always flattened and nail-like.

The Manus.—The manus has the power of complete pronation and supination; the carpus is relatively high and narrow, and its proximal articular surface is much arched from side to side; the unciform and magnum have great relative height, and a centrale may or may not be present; the metacarpals have characteristic globular extremities, in which the keels, grooves, and sesamoids are little developed, and disappear completely in the higher forms; the phalanges are elongate, and the unguals may be compressed and clawlike or depressed and nail-like; the pollex is very generally present and, with the exception of the marmosets and some lemurs, is always opposable and nail-bearing; its opposability, like that of the hallux, is indicated by the character of its articulation with the trapezium.

The chief characters of the other parts of the skeleton are the following: The teeth have brachyodont crowns with low rounded cusps; the incisors are very generally reduced to two above and below, but exceptionally may be two above and one below (*Tarsius*), or, again, one above and below, with rodent-like modification (*Mixodectes*, *Microsyops*, *Metacheiromys*, and *Cheiromys*); the premolars rarely become molariform, but progressively decrease in number to two above and below; the orbit, except possibly in a few instances, is always encircled by bone posteriorly, the orbital and temporal fossæ are separated by a bony partition in the higher forms, and the eyes are directed forward; the mandibular rami are early coössified in the more advanced species; the limbs are elongate and well developed, and clavicles are always present; the coracoid is large, the olecranon is short, and the fibula is very generally unreduced; the astragalus is without an astragalar foramen.

[To be continued.]

Art. XVI.—*On Ceric Chromate;* by Philip E. Browning and Charles P. Flora.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIV.]

Böhm* in a recent paper descriptive of his thorough investigations of the application of chromic acid to the separation of the cerium earths, states that when the mixed oxides of cerium lanthanum and didymium are brought in contact with a calculated amount of chromic acid, a little water added, and heat applied for a time, an orange red amorphous powder remains which proves to be a basic ceric chromate. In connection with a study of the methods of separating the cerium earths, begun last summer, we had occasion to make an experiment similar to that described by Böhm, differing possibly in this respect, that we used a decided excess of the chromic acid (100 grms. of the oxides with 150 grms. of chromic acid and 200$^{cm^3}$ of water).

The product which we obtained was a bright scarlet crystalline salt, which, when washed sparingly with water and dried over sulphuric acid, became a little darker in color but retained its crystalline condition. Examined under the microscope the salt appeared homogeneous, and the crystalline form orthorhombic, the prevailing habit being prismatic, $m \wedge m'''$, $110 \wedge 1\bar{1}0$, being approximately 58° C. The macropinacoid, a (100), is generally present, the brachypinacoid, b (010), is well developed, and a flat brachydome and the basal plane, c (001), are the terminating forms. The crystals are etched or pitted, are slightly pleochroic, and exhibit parallel extinction and low birefringence. When treated with water the salt loses chromic acid and becomes an orange yellow. It may be heated to about 150° C. without loss of weight. Between 150° and 180° C. it loses water and becomes brownish red, still retaining much the same original exterior form. Above 180° C. it decomposes. It is quite readily soluble in dilute acids, especially sulphuric acid, and is easily decomposed by potassium or sodium hydroxide into the alkali chromate and ceric hydroxide. The ceric hydroxide thus formed is quite readily soluble in acids and promises to be a convenient starting point for the preparation of ceric salts. Qualitative tests proved the absence of both yttrium and didymium.

Analysis of the salt gave the following results: Five closely agreeing determinations of water, six determinations of ceric oxide, among which the greatest variation was about one per cent, and sixteen determinations of chromic acid showing as the greatest variation about two per cent, gave the averages tabulated below:

* Zeitschr. angew. Chem., xv, 1282.

Salt examined.		$Ce(CrO_4)_2 2H_2O$ calculated.	
CeO_2	41·94	CeO_2	42·14
CrO_3	49·61	CrO_3	49.04
H_2O	8·82	H_2O	8·82
	100·37		100·00

From these analyses we feel justified in assuming the crystalline salt to be a close approximation to a compound whose constitution would be expressed by the symbol $Ce(CrO_4)_2 \cdot 2H_2O$.

The material from which the mixed oxides used in this work were obtained was a mixture of sulphates of cerium lanthanum and didymium, carrying a trace of yttrium.

The authors are indebted to Mr. J. C. Blake for the crystallographic examination.

Art. XVII.—*The Effects of Changes of Temperature on Permanent Magnets;* by Hiram B. Loomis.

The following paper is an account of some experiments undertaken to determine more accurately, if possible, the kind of change which takes place when a magnet is heated and cooled after it has been brought to the "permanent state." The subject will be considered under the following heads: I. Historical Sketch. II. Experiments and Calculation of Results. III. Discussion of Results.

I. *Historical Sketch.*

A. *Investigations on the change in magnetic moment due to change in temperature.*—About 1825, Kupfer* magnetized a steel bar and placed it in a water bath at the temperature of the room. Near it he suspended a magnetic needle and determined the period of 300 swings. The bath was then heated to 100 C. and the period of 300 swings was again determined. The bar was then alternately heated and cooled between these limits of temperature and similar observations taken. Kupfer thus learned that if a permanent magnet is heated above its temperature of magnetization its magnetic moment decreases, that on again cooling the moment increases but not enough to make up for the first loss, and that this is true for the first three or four times it is heated and cooled.

In 1851, Lamont† found that when a permanent magnet was alternately heated and cooled fifteen or sixteen times between fixed limits of temperature, it reached a permanent state in which it had a definite magnetic moment for a given temperature, to which it always returned when brought to that temperature, provided only it had never passed beyond the temperature limits mentioned above. The higher the temperature, the smaller was the magnetic moment.

Riess and Moser‡ also experimented on the change in magnetic moment by swinging magnets in the earth's field and determining the period of vibration. For needles 34 lines long they found the following formula held:

$$I' = I\,[1 - 0{\cdot}000324\,(t' - t)d],$$

in which I and I′ are the intensities of magnetization at the temperatures t and t' on the Reaumur scale, and d is the diameter of the magnets. For needles two inches long the numerical factor is 0·000432, showing that the proportional change in intensity of magnetization is greater in shorter magnets.

* Wiedemann's Electricität, iii, p. 753.
† Lamont, Pogg. Ann., lxxxii, p. 440, 1851.
‡ Riess and Moser, Pogg. Ann., xvii, p. 425, 1829.

The temperature limits were 0° and 80° R. By swinging their magnets at different temperatures they found the change in moment proportional to the difference in temperature, as is shown by their formula.

Prof. G. Wiedemann* has made some careful investigations on the influence exerted by the temper of the steel and the original intensity of magnetization. He used bars 22^{cm} long and $1{\cdot}35^{cm}$ in diameter. Before they were magnetized these bars were placed alternately in melting snow and boiling water fifteen times, in order to bring the steel itself as far as possible into such a state that alterations in temperature would produce no structural change. The bars were magnetized in a coil at a temperature of 0° C. They were then carefully placed in a box of sheet copper before the needle of a magnetometer and the deflection was observed by telescope and scale. The temperatures of 0° and 100° C. were obtained by means of melting snow and boiling water. His results for magnets that have reached the permanent state show that in case of hard steel magnets the change in moment is nearly proportional to the moment at 0° C., while for tempered and soft steel magnets, the ratio of change to the moment at 0° C. increases with the moment. As his results give a good idea of the size of the changes under discussion, I append the following table from his paper.

With reference to the theory of these changes Prof. Wiedemann says: "Besides the permanent effect due to an alteration in temperature there is a temporary change. Each heating diminishes the permanent moment of the molecules. Moreover, for the time being, it loosens the particles of the body and lessens the strain in which they have been placed by the action of external forces, therefore they return a little toward their first position of equilibrium, in which they were held by the forces acting between them before the external forces came into play. Heating thus diminishes the magnetization temporarily; but, on cooling, the molecules return to their former position and the lost magnetization is regained. We can produce entirely analogous phenomena if we change the temperature of bodies which have suffered a change of form (torsion) as a result of mechanical forces, and observe the increase and decrease of this on heating and cooling."

Barus and Strouhal† carefully distinguished the mechanical effect of heating from the purely magnetic effect. They found that a temperature of 20° or 30° C. above that of the water in which a glass-hard steel rod was dipped in hardening produced quite perceptible annealing effects. This change in the hard-

* G. Wiedemann, Pogg. Ann., c, p. 235, 1852; ciii, p. 563, 1858; cxxii, p. 355, 1864.

† Bull. U. S. G. S., No. 14, p. 151.

M_0	M_{100}	M'_0	N_0	N_{100}	$\frac{M_0-M_{100}}{M_0}$	$\frac{M_0-M'_0}{M_0}$	$\frac{M_0-N_0}{M_0}$	$\frac{N_0-N_{100}}{N_0}$
			I. *Hard steel bar.*					
71·5	41·5	44·8	37·	33·2	0·420	0·373	0·483	0·103
134·5	89·2	96·	85·5	77·8	0·321	0·286	0·364	0·090
195··	134·3	146·2	133·3	120·	0·311	0·250	0·316	0·100
			II. *Tempered steel bar.*					
44·	27·	30·	29·	27·	0·386	0·318	0·341	0·0690
148·5	107·2	114·5	110·3	101·	0·278	0·229	0·257	0·0814
219·5	165·	179·	172·	156·	0·249	0·184	0·216	0·0930
317·	239·	260·7	251·2	226·	0·246	0·178	0·207	0·1003
			Soft steel bar, No. 1.					
85·	45·		38·	33·2	0·471		0·553	0·126
141·	73·5		68·5	57·	0·479		0·514	0·168
193·	99·		101·	78·5	0·487		0·478	0·223
209·5	109·5		115·	88·2	0·477		0·451	0·233
			Soft steel bar, No. 2.					
95·5	49·7	54·2	45·	39·	0·479	0·432	0·529	0·133
136·5	73·	81·5	69·	59·	0·465	0·403	0·495	0·145
174·8	92·5	108·3	93·4	76·	0·471	0·378	0·466	0·186
			Very soft steel bar which had been heated and slowly cooled many times.					
51·5	34··5	37·			0·330	0·282		
80·5	54·5	58·			0·323	0·279		
113·	76·	82·			0·328	0·274		
159·5	103·3	116·5			0·353	0·270		
181·	113·5	131·			0·373	0·277		

M_0 is the intensity of magnetization before any change in temperature has taken place; M_{100}, when first heated to 100° C.; M'_0, after being again cooled to 0° C. N_0 and N_{100} are the intensities of magnetization at the temperatures indicated by the subscripts after the magnet has been heated and cooled fifteen times.

ness of the steel would naturally affect the magnetization. According to their experiments, if a glass hard steel rod is thoroughly annealed by being kept at the temperature of boiling water for a day or two and then magnetized to saturation at the temperature of the room, the loss in magnetization on being heated to the boiling point is relatively small and is nearly independent of the time it is kept there. Nearly the whole change takes place during the first ten minutes. On the other hand, if the bar is not first annealed, the change is much larger and is not complete after twenty-two hours heating.

B. *Investigations on the effect of change of temperature on*

the distribution of magnetism.—Kupfer* determined at two different temperatures the period of vibration of a short needle placed opposite different parts of a long magnet and found the proportional change in distribution greater at the ends than in the middle of the bar. All his measurements were made before the bar had reached the permanent state.

Poloni† measured the distribution at various temperatures, by slipping a coil from different parts of the magnet to such a distance that the magnet exerted practically no effect and measuring the quantity of electricity thus induced. He worked between the temperatures 0° and 200° C., using an oil bath to obtain his high temperatures. The changes were quite regular between 0° and 180° C., but were very large near 190° C. Between 0 and 180 C., he found that the following formula held:

$$M = A[1 + k^{-l} - k^{-x} - k^{(l+x)}]$$

in which M is the induction in the magnet at a distance x from one of the ends; l, the length of the magnet; A, a quantity depending only on the temperature, while k is sensibly constant for a given magnet.

II. *Experiments and Calculation of Results.*

The existence of a permanent state, in which the moment of a magnet increases or diminishes as its temperature falls or rises, being now well established, the reason for this change becomes an interesting subject for investigation. In the hope of obtaining some clue to its real nature, the following experiments were undertaken. They were planned to determine: first, the change in magnetic moment due to change in temperature in bars of the same cross-section but of different lengths; second, the change in distribution due to change in temperature. The experiments will be considered in the above order.

A. *Experiments on the change of the magnetic moment of magnets of different lengths but of the same cross-section.*—Stubb's steel wire of square cross-section, 0·159^{cm} square, was cut into lengths of approximately 5·5^{cm}, 8·3^{cm}, and 22^{cm}. The steel was soft and was used of the same temper as purchased. The bars were annealed in boiling water, magnetized to saturation in a coil, and were in the permanent state when used. The period of vibration in the earth's field was determined at 11° and 99° C. A double box of thin sheet zinc was used to keep the magnets at the required temperatures. In the top of the box was a round opening into the interior, in which a cork holding a thermometer and a glass tube was inserted. Through this tube passed a short wire, which supported the magnet and was suspended from the ceiling by cocoon silk. The suspen-

* Kupfer, Pogg. Ann., xii, p. 133.

† Poloni, Beibl. v, 802. Atti della R. Acad. dei Lincei, v, p. 262, 1881.

sion was thus quite long and was but little exposed to the action of the heat. The bulb of the thermometer was close to the magnet. In the side of the box was another opening, covered with glass, through which a mirror attached to the magnet was observed, and the time of vibration thus determined. The temperature of the space in which the magnets swung was kept quite constant at 11° C. or 99° C., by passing a current of cold water or steam through the space between the two parts of the double box. For the lower temperature city water was used direct from the faucet.

The magnets and the mirror used in observing their vibrations were weighed. The lengths of the magnets were measured at the ordinary temperature of the room, 18° C. The corrected lengths for 11° and 99° C. were obtained by the following formulæ:

$$L_{11} = L\,(1 - 7 \times 0{\cdot}000011),$$
$$L_{99} = L\,(1 + 81 \times 0{\cdot}000011),$$

in which L_{11} and L_{99} are the lengths at the temperatures indicated by the subscripts, L is the observed length, and 0·000011 is the coefficient of linear expansion of untempered steel. The moments of inertia for the magnets at each temperature were calculated as follows:

$$I_{11} = m\frac{L_{11}^{\,2} + b^2}{12},$$

$$I_{99} = I_{11}\frac{L_{99}^{\,2}}{L_{11}^{\,2}},$$

in which m is the mass of the magnet and b its thickness. The mass of the mirror and of the appliances by which it was fastened to the magnet was 0·4245 grms., and calling its radius of gyration 0·2^{cm} the moment of inertia due to it was 0·0170, which was added to that of the magnets. No correction was made for the rest of the suspending apparatus; its mass was always less than 0·10 grms., and it consisted principally of a piece of fine wire about 25^{cm} long; and its radius of gyration was exceedingly small, being a fraction of the diameter of the wire. The silk suspension was about 3·5 meters long. No allowance was made for the effect of torsion, as the magnet could be turned 360° without producing enough difference in azimuth to be detected by a telescope and scale at a distance of 3 meters. The formulæ for the magnetic moments are:

$$M_{11} = \frac{4I_{11}'\pi^2}{T^2H}, \qquad M_{99} = \frac{4I_{99}'\pi^2}{T^2H},$$

in which I′ denotes the total moment of inertia of the system at the temperature indicated: T, the period of a complete vibration; and H, the horizontal intensity of the earth's magnetic force. H was taken as equal to 0·2. It has been deter-

mined by several previous observers in the room in which the work was done; and as there were no local disturbing iron masses, that part of the building being kept free from iron, it may be taken as within one half of one per cent of correct.

Specimen Calculation.—Magnet No. 9.

Length at 18° C.	$16{\cdot}40^{cm}$
Mass	$3{\cdot}609^{grms}$
Period of vibration at 11° C.	$10{\cdot}435^{sec}$
Period of vibration at 99° C.	$10{\cdot}812^{sec}$
$L_{11}=16{\cdot}40\,(1-7\times0{\cdot}000011)$	$16{\cdot}399^{cm}$
$L_{99}=16{\cdot}40\,(1+81\times0{\cdot}000011)$	$16{\cdot}414^{cm}$
$I_{11}=m\dfrac{L_{11}+b^2}{12}=\dfrac{3{\cdot}609\,(268{\cdot}92+0{\cdot}02)}{12}$	80·883
$I_{99}=I_{11}\dfrac{L_{99}^{\,2}}{L_{11}^{\,2}}=80{\cdot}883\,\dfrac{269{\cdot}43}{268{\cdot}91}$	81·034
$I_{11}'=80{\cdot}883+0{\cdot}017$	80·900
$I_{99}'=81{\cdot}034+0{\cdot}017$	81·051
$M_{11}=\dfrac{4I_{11}'\pi^2}{T_{11}^{\,2}H}=\dfrac{4\times80{\cdot}9\times9{\cdot}8696}{108{\cdot}889\times0{\cdot}2}$	146·64
$M_{99}=\dfrac{4I_{99}'\pi^2}{T_{99}^{\,2}H}=\dfrac{4\times81{\cdot}051\times9{\cdot}8696}{116{\cdot}899\times0{\cdot}2}$	136·80

The results of this series of experiments are given in the following table: and figure 1 gives a curve in which $\dfrac{M_{11}-M_{99}}{M_{11}}$ is platted as a function of the intensity of magnetization.

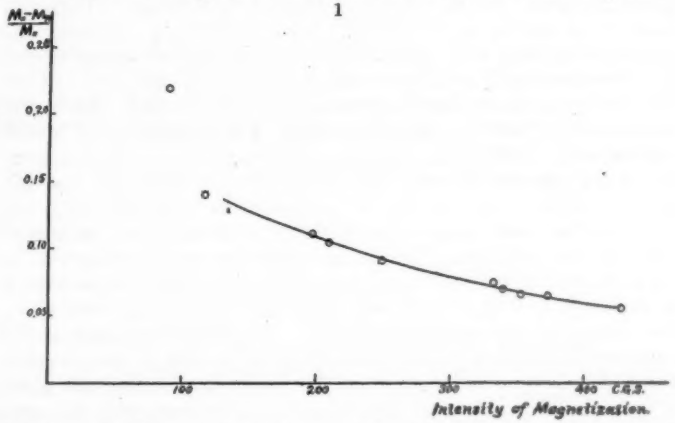
Magnets of Square Cross-Section. ($0{\cdot}159^{cm}$ square).

Number of magnet.	Length of magnet.	Moment at 11° C. M_{11}	Moment at 99° C. M_{99}	$\dfrac{M_{11}-M_{99}}{M_{11}}$	Intensity of magnetization.
3	21·53	232·92	219·88	0·056	427
5	22·00	207·08	193·64	0·065	372
9	16·40	146·64	136·80	0·067	352
15	16·31	139·76	129·28	0·075	338
4	11·23	94·76	88·04	0·071	333
6	10·80	72·41	65·72	0·092	249
7	8·15	43·04	38·48	0·105	208
8	8·17	40·48	35·92	0·112	196
13	5·49	16·72	14·44	0·141	117
12	5·40	12·04	9·84	0·220	88

B. *Experiments on the change in distribution due to change in temperature.*—The apparatus employed was suggested by the late Prof. Henry A. Rowland, under whose direction the investigation was conducted, and will be best understood from the diagram in fig. 2. A and B are two cylindrical soft steel magnets (Stubb's steel of the same temper as when purchased) $30{\cdot}1^{cm}$

long, and 0·55^{cm} in diameter. They were magnetized to saturation in a coil, the magnetic circuit being completed by an iron casting of suitable size and shape. They were then brought to the permanent state by alternate heating and cooling. In both ends of each, holes were bored and threads cut. The depth of these holes in magnet A was 8^{mm} at each end. In magnet B

1



the hole at the south end was 11^{mm} deep; that at the north end 7^{mm}. In the experiment the magnets were placed perpendicular to the earth's field. Pieces of brass rod, H,H,H,H, of the same diameter as the magnets were screwed into their ends and acted as guides for the two coils (to be described presently), so that after the coils had been slipped off the magnets, they could be slipped back again without trouble. DD is a brass

2

rod about 1·5 meters long, holding two magnets together in the position shown in the figure. C,C are pieces of non-conducting material to keep the magnets from changing temperature by conducting along the rod DD. E and F are two coils of very fine wire wound on paper tubes which just fit the magnets. They consisted of 150 turns (five layers of 30 turns each), and were about 7^{mm} wide. Their frames were joined by a brass rod, PP, of such length that when the coil E was at the center of the magnet B, the coil F was also at the center of the magnet A. By means of this rod they could be moved simultaneously over corresponding portions of the two magnets. At G is a gauge which regulates the distance the coils are moved at a time, so that as they are moved step by step from one end of

the bar to the other, the steps will be of equal length. By loosening a screw the coils may be moved from the middle of the magnets to either end at one step. The cross-sections of two cylindrical double boxes, made of sheet zinc, are indicated at S and T. At K,K are openings in which corks holding thermometers were inserted. At L,L are openings into the spaces between the two parts of the double boxes. Through these a current of steam or cold water was passed to keep the space containing the magnets at the requisite temperature. The temperatures employed were 14° C. and 99°·5 C. City water direct from the faucet was used to produce the lower temperature, and a fairly constant temperature was easily maintained. NM,NM, are other openings by which the magnets were introduced and through which the bars DD and PP passed. They were about $2{\cdot}5^{cm}$ in diameter and 20^{cm} long, and were stuffed with cotton, the better to maintain the temperature of the interior. The exploring coils were connected up with an ordinary astatic galvanometer of rather low resistance in such a way that the currents induced by moving them along the magnets opposed each other. An earth inductor and a resistance box were included in the circuit, and in each experiment the galvanometer readings were standardized by the earth inductor. Beginning at the middle of the magnets, the coils were moved step by step to one end, the throw of the needle being observed for each step. The coils were moved so far in the last step that practically no lines of induction passed through them, as was determined by experiment. Similar observations were made for the other half of the magnets. In this way was measured the excess of the number of lines of induction passing from a certain section of one magnet into the air over that passing out of the corresponding section of the other magnet, thus giving the difference of distribution in the two magnets. These measurements are taken first when A and B are both at 14° C., and again when A is at 14° C. but B at 99°·5 C. The difference between the two sets after they have been reduced to the same scale by the earth inductor readings is evidently the change in distribution in B due to the change in temperature. By this method the quantity observed is of about the same magnitude as the quantity we desire to obtain ; the greatest throw of the needle was but little over twice the largest difference obtained on subtracting the two sets of observations.

To get the distribution of magnetism of the bars, the difference in distribution was first measured as above indicated, then the connection of the coils was changed so that the currents induced in the two coils were in the same direction, and the sum of the distributions was obtained in the same way. In

this case extra resistance had to be added from the resistance box to keep the readings on the scale.

Calculation of Results.

The formula for the ballistic galvanometer is

$$Q = k \sin \frac{\theta}{2}$$

in which Q is the quantity of electricity; k, a constant factor; and θ, the angular throw of the needle. The observations were made with telescope and scale. Letting d represent the observed throw and r the distance of the mirror from the scale,

$$\tan 2\theta = \frac{d}{r}$$

Expanding $\sin \frac{\theta}{2}$ we have

$$\text{Sin } \frac{\theta}{2} = \frac{d}{2r}\left[1 - 0{\cdot}344\left(\frac{d}{r}\right)^2 + \right]$$

This formula was used in reducing the large readings.

The earth inductor readings were taken frequently and varied but little throughout the experiment. The throw due to the earth inductor when both magnets were at 14° C. was 39·5 scale divisions; when one magnet was at 99°·5 C. and the other at 14° C., it was 37·8. Corresponding throws of the needle due to the slipping of the exploring coils over various portions of the magnets were averaged. The average throws taken when one magnet was hot and the other cold was multiplied by $\frac{39{\cdot}5}{37{\cdot}8} = 1{\cdot}045$ to reduce to the same scale as the readings taken when both magnets were at 14° C. Correspondings measurements were then subtracted to get the difference of distribution caused by change in temperature in terms of the scale divisions. The reduction to absolute measurement was as follows: The effective area of the earth inductor, as determined by previous observers, was $20{,}716^{\text{sq cm}}$. The total number of lines of induction cut by turning the earth inductor was $2HA = 8{,}286{\cdot}4$. The throw was 39·5 scale divisions, therefore each scale division of throw caused by the movement of the exploring coils corresponded to $8{,}286{\cdot}4 \div (39{\cdot}5 \times 150) = 1{\cdot}398$ C.G.S. lines of induction. The factor 150 is due to the 150 turns of the exploring coils. The change in distribution as given in scale divisions was then multiplied by 1·398, giving the change in distribution in C.G.S. lines of induction for each $2{\cdot}17^{\text{cm}}$ of length, that being the distance the coils were moved at each step. In determining the difference of distribution the angles observed were quite small; the largest was

less than 2°, making the angular throw of the needle less than one degree. The deflections in scale divisions were therefore taken as proportional to sin $\frac{\theta}{2}$. The error in case of the largest reading would not exceed one part in 3,500; and as the results are obtained by subtraction of two throws, the error in the result may be neglected.

Specimen Calculation.

Magnet A.—Middle to North End.

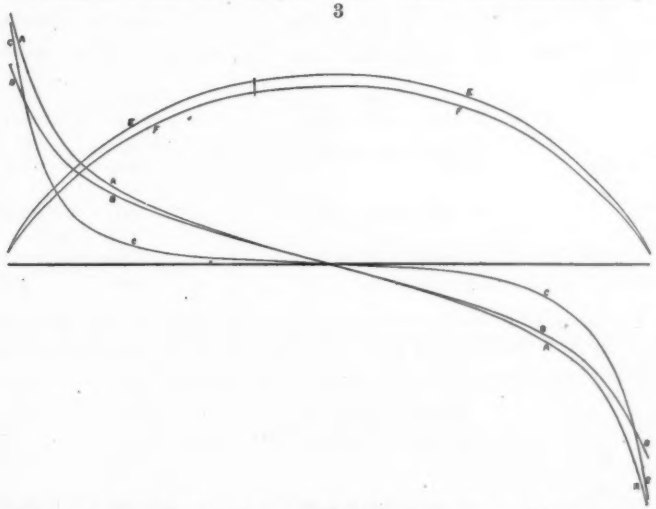
Steps.	Average observed throw at 14° C.	Average observed throw at 99°·5 C.	Corrected throw at 99°·5 C.	Difference in distribution in scale divisions.	Difference in distribution in C.G.S. lines of inductions.
I	18·0	17·5	18·3	— 0·3	— 0·4
II	18·4	18·1	18·9	— 0·5	— 0·7
III	11·8	12·6	13·2	— 1·4	— 2·0
IV	— 7·2	— 4·2	— 4·4	— 2·8	— 3·9
V	—34·3	—27·2	—28·4	— 5·9	— 8·3
VI	—42·0	—27·7	—28·9	—13·1	—18·3
VII	—49·0	—19·4	—20·3	—28·7	—40·2
End	— 5·4	— 2·2	— 2·3	— 3·1	— 4·3

In getting the sum of the distributions it was found necessary to make use of the formula on p. 187, because the angles were too large to take sin $\frac{\theta}{2}$ proportional to tan 2θ. The corrected readings were reduced to absolute measure in the way just described. Thus we have the sum and difference of the linear distribution of the two magnets in absolute measure. One half the sum plus one half the difference gives the distribution of one magnet; and one half the sum minus one half the difference gives that of the other. The distribution at the higher temperature was obtained by subtracting the change in distribution due to the heating from the distribution at the lower temperature. The induction at each point of the magnet was obtained by adding up the number of lines of induction passing out of the magnet beyond that point.

Tables of the results for magnets A and B are given on pages 192 and 193. The first column gives the distance of the exploring coils from the centers of the magnets at the end of each step. The second and fourth columns give the number of C.G.S. lines of induction passing out from the magnet at 14° C. and 99°·5 C. respectively in the step of the coil shown in the first column. The third column gives the change in distribution. The fifth and sixth columns give the magnetizations at the two temperatures, i. e., the number of C.G.S. lines of induction per square centimeter of cross-section passing through the mag-

net at the point indicated. In these columns two values are given for the middle point of the magnet, calculated from the two ends, and serve to indicate the degree of accuracy attained. The second and third columns, from which all the others are calculated, give the means of at least five or six separate determinations which agree well among themselves. The results were further checked by slipping the coils from the middle of the magnets clear off each end at both temperatures. The variation between this measurement and the others was always less than one half of one per cent. This was considered quite

3



good, as it was impossible to slip the coils over this whole distance as quickly as they were slipped over the small divisions. In figures 3 curves for magnet A are given as follows: AA is the distribution curve at 14° C. BB is the distribution curve at 99°·5 C. CC is a curve showing the change in distribution due to change in the temperature (14°−99°·5 C.). The scale of ordinates is ten times that in AA and BB. EE is a curve giving the induction in the magnet at 14° C. FF is a curve giving the induction in the magnet at 99°·5 C.

The tables on pages 192 and 193 together with the curves for distribution give us sufficient data to calculate the magnetic moments of the magnets A and B at both temperatures. In the tables we are given n, the number of lines of induction issuing from little divisions of the bar throughout its length, as well as the distance d of these divisions from the center of the magnet. A first approximation to the moment is given by the formula

$$M = \frac{1}{4\pi} \sum nd.$$

To this value the following correction was added: If AB in figure 4 is the length of one of these divisions of the magnet, and CD a part of the distribution curve supposed to be straight, then the area ABDC represents the number of lines of induction issuing from the magnet in the length AB. Let F be the center of gravity of the triangle CED. It is evident that the portion of the distribution represented by the triangle should be multiplied by the abscissa of F, not of H, therefore a correction $\sum$ area CED$\times$GH was added to the summation already given. From this calculation the following results were obtained:

	Magnets.	A.	B.
M_{14}	Moment at 14° C.	2298	2060
$M_{99°5}$	Moment at 99·°5 C.	2140	2018
$M_{14} - M_{99°5}$	Loss.	158	142
$\frac{M_{14} - M_{99°5}}{M_{14}}$	Proportional loss.	0·0687	0·0689
	Intensity at 14° C.	322	289
	Intensity at 99·°5 C.	300	283

The magnetic moments were also determined by the method used in the first part of this investigation with the following results:

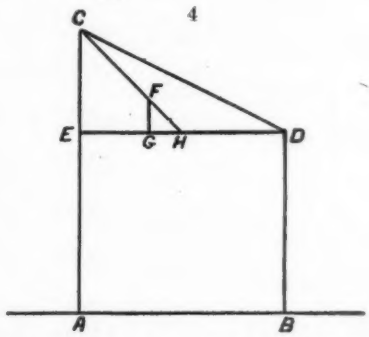
	Magnets.	A.	B.
M_{14}	Moment at 14° C.	23 9	2091
$M_{99°5}$	Moment at 99°·5 C.	2197	1947
$M_{14} - M_{99°5}$	Loss.	166	146
$\frac{M_{14} - M_{99°5}}{M_{14}}$	Proportional loss.	0·0686	0·0687
	Intensity at 14° C.	339	298
	Intensity at 99°·5 C.	316	277

The difference between these two sets of values is considerable, amounting to two per cent in the case of magnet A. This may be due to the fact that only an approximation could be made to the moments of inertia of the magnets because of the holes in the ends, where a slight error would affect the result materially, as the distance from the center was above 15^{cm}. The moments of inertia were calculated by dividing the magnet into two parts, an inner core and an outer shell extending beyond the core at both ends. On the other hand, it is to be noticed that the ratios $\frac{M_{14}\ M_{99·5}}{M_{14}}$ differ by less than one part in 300. In this ratio the moment of inertia of the magnet is eliminated.

In his paper on magnetic distribution, Prof. Rowland gives the following formula for the linear distribution in a magnet

$$\lambda = \frac{\mathfrak{H}\ (e^{rx} - e^{-rx})}{4\pi\sqrt{RR'}(e^{rb} + e^{-rb})},$$

in which R is the resistance of unit length of the rod, R′ is the resistance of the medium along unit length of the rod, $2b$ is the length of the magnet, x is the distance from the center of the magnet, and $r = \sqrt{\frac{R}{R'}}$.



At 14° C. the formula for magnet A may be written

$$4\pi\lambda = 167\ \frac{e^{0\cdot125x} - e^{-0\cdot125x}}{e^{0\cdot125b} + e^{-0\cdot125b}};$$

at 99°·5 C.,

$$4\pi\lambda = 161\ \frac{e^{0\cdot1242x} - e^{-0\cdot1242x}}{e^{0\cdot1242b} + e^{-0\cdot1242b}}.$$

III. *Discussion of Results.*

The first series of experiments shows that the proportional change in magnetic moment due to change in temperature is greater for short than for long magnets; and that the magnet having the greater intensity of magnetization suffers the less proportional change. This last result is not in agreement with the observations of Wiedemann given on page 180. A little consideration will show, however, that Wiedemann's method cannot be relied upon to give accurate results for the change in magnetic moment. He placed a magnetometer needle before the magnet and observed the deflection of the needle for two temperatures of the magnet. If the center of magnetic attraction had remained at the same point of the magnet during the

temperature changes, his method would have given correct results; but, as will appear from the second part of this investigation, the ends lose a greater proportion of their magnetism than does the middle, and therefore the center of magnetic

Magnet A.

Distance from center of magnet.	Distribution at 14° C.	Change in distribution.	Distribution at 99°·5.	I_{14} Induction at 14° C.	$I_{99\cdot5}$ Induction at 99°·5.	$\frac{I_{14}-I_{99\cdot5}}{I_{14}}$
	70·1	− 4·3	65·8			
15·20				296·	278·	·060
	428·5	−40·2	388·3			
13·03				2106·	1918·	·089
	285·4	−18·3	267·1			
10·86				3309·	3044·	·080
	204·9	− 8·3	196·6			
8·68				4175·	3875·	·071
	146·8	− 3·9	142·9			
6·51				4795·	4479·	·065
	91·2	− 2·0	89·2			
4·34				5180·	4586·	·062
	56·6	− 0·7	55·9			
2·17				5419·	5092·	·060
	18·6	− 0·4	18·2	{ 5498·	{ 5169 }	
0				{ 5453·	{ 5126 }	·060
	−17·9	0·	− 17·9			
2·17				5377·	5050·	·060
	−55·5	+ 0·4	− 55·1			
4·34				5143·	4818·	·063
	−96·9	+ 2·5	− 94·4			
6·51				4734·	4420·	·066
	−142·1	+ 3·2	−138·9			
8·68				4134·	3834·	·072
	−199·9	+ 6·2	−193·7			
10·86				3289·	3015·	·083
	−276·3	+14·8	−261·5			
13·03				2122·	1910·	·100
	−432·6	+39·2	−393·4			
15·20				294·	247·	·159
	− 69·7	+11·2	− 58·5			

attraction travels towards the middle of the magnet as the temperature rises. Since the attraction varies inversely with the square of the distance, and since the quantities to be determined are obtained by subtracting the observed quantities, it is evident that the change in magnetic distribution renders Prof. Wiedemann's method inaccurate. This error does not enter in the present investigation, in which the magnetic moments were

determined by swinging the magnets in the earth's field. The results obtained are summed up in the table on page 184.

The second series of experiments shows that the proportional change in distribution of magnetism due to change of tempera-

Magnet B.

Distance from center of magnet.	Distribution at 14°	Change in distribution.	Distribution at 99°·5.	I_{14} Induction at 14°.	$I_{99\cdot5}$ Induction at 99°·5.	$\frac{I_{14}-I_{99\cdot5}}{I_{14}}$
	61·0	− 3·9	+ 57·1			
15·20				258·	242·	·062
	359·5	−39·6	+319·9			
13·03				1777·	1594·	·103
	227·6	−15·1	+212·5			
10·86				2738·	2491·	·090
	159·7	− 6·0	+153·7			
8·68				3413·	3141·	·079
	139·4	− 3·4	+136·0			
6·51				4002·	3716·	·071
	108·1	− 2·1	+106·0			
4·34				4458·	4163·	·066
	81·4	− 1·5	+ 80·0			
2·17				4802·	4501·	·062
	43·5	− 0·1	+ 43·4			
0				4986· 4950·	4685· 4650·	·060
	3·6	+ 0·7	+ 4·3			
2·17				4965·	4668·	·060
	− 36·2	+ 1·1	− 35·1			
4·34				4812·	4520·	·060
	− 79·8	+ 2·0	− 77·8			
6·51				4475·	4191·	·063
	−128·3	+ 2·4	−125·9			
8·68				3933·	3659·	·069
	−188·6	+ 6·6	−182·0			
10·86				3136·	2890·	·078
	−266·3	+19·0	−247·3			
13·03				2011·	1845·	·082
	−406·4	+35·4	−371·0			
15·20				294·	277·	·057
	− 69·7	+ 4·1	− 65·6			

ture is greatest at the ends and least in the middle of the magnet. A glance at the tables given above, or at the curves in fig. 3, will show this. This is different from the result obtained by Poloni, who found the proportional change sensibly constant throughout the magnet. It could not be expected that the small difference noticed here could be detected by his method, which consisted in measuring two large quantities and

subtracting them in order to obtain a small difference. In the method employed in this research the quantities measured differed but little in size from the quantities desired, and much greater accuracy was easily obtained.

The following is suggested as the explanation; Prof. Ewing has recently made an important addition to Weber's theory of magnetism, in claiming that the forces which hold the little molecular magnets in position are largely the mutual attractions and repulsions of these molecular magnets among themselves. In applying Ewing's theory to the case in hand let us consider a row of magnetic molecules ABC, etc.

A B C H I J K L

J is held in position by the action of H,I, etc. on the one side and K,L, etc. on the other side, while A has only B,C, etc. to act upon it. It is evident that the force holding J in position is greater than that acting on A. Suppose the bar of which this line of molecules is a part is heated. If in this process the energy of vibration of A and J receive equal increments, it is evident that the increase in the amplitude of vibration of A will be greater than that of J. The magnetic moment contributed by each molecule is the moment of the molecule resolved along the direction of magnetization of the bar. The moment contributed by A would therefore suffer a larger proportional loss on heating than that contributed by J, and so the loss would be greatest at the ends. This explanation will also account for the fact that the proportional change in magnetic moment is greater in short magnets, because in short magnets the end regions of these lines of molecular magnets will naturally form a larger part of the whole line than in long magnets. We should also expect these lines of molecular magnets to be longer when the intensity of magnetization was greater. This would account for the fact that the change in magnetic moment due to temperature changes is less the greater the intensity of magnetization. This appears from the curve given in fig. 1. There are other facts which point in the same direction: When a magnet is heated before it has reached the permanent state, Kupfer found, as already stated, that the proportional permanent loss was greatest at the ends. In some rough tests I have made on this point, heating the bar almost to redness, I have found the permanent proportional loss at the ends nearly twice as great as at points near the center of the magnet. This would naturally follow from Ewing's theory, for the force holding the end magnetic molecules in position being less, they would be more easily set into such violent vibration as to swing out of one position of equilibrium into another.

Western Springs, Ill.

Art. XVIII.—*On the Chemical Composition of Axinite;* by W. E. Ford.

Introduction.—Axinite has long been one of the important silicates whose chemical composition has been in doubt. A number of analyses have been made of material from different sources and of widely differing character, but without revealing any substantial agreement in the ratios between the various oxides. Two formulas are generally given by Dana, Hintze, and other authorities, which disagree with each other to a marked extent; one as derived by Rammelsberg, $HR_2BAl_2(SiO_4)_4$; the other by Whitfield, $H_2R_4(BO)Al_3(SiO_4)_5$. Still a third formula, $HR_4(Al,B)_3(Al.SiO_3H)(SiO_4)_6$, is given by Groth in his *Tabellarische Übersicht der Mineralien.* In view of the uncertainty regarding the composition of this important mineral the present investigation was undertaken with the hope that a few carefully executed analyses would furnish the data needed for determining the chemical formula.

Material for Analysis. — Axinite crystals of beautiful quality from the classical locality of Bourg d'Oisans in Dauphiné were used in making Analysis No. I. The material was broken up coarsely and the crystalline fragments picked over carefully by hand, only clear and transparent pieces which were entirely free from any associated mineral being used. Analysis No. II was made on material from Obira, Province of Bungo, Japan, which was selected with the same care as described above. This is a new occurrence of axinite, of a yellowish brown color with a resinous luster, the material being transparent to translucent. The crystals will be described in a note at the end of this article. Axinite from Franklin, N. J., analyzed by Genth* and studied crystallographically by Penfield* has also been examined; well authenticated specimens of this material having been preserved in the Brush collection. In this case, however, it was only found necessary to supplement the work of Genth by making new determinations of water.

Method of Analysis.—In general the method of analysis need only be briefly described. Silica was determined as usual, with the precautions suggested by Hillebrand.† The sesquioxides were separated from manganese and other bases by a basic acetate precipitation, and manganese was weighed as the protosesquioxide after precipitation by bromine vapor. Calcium and magnesium were determined as usual. Fer-

* This Journal (3), xli, 394, 1891.

† Jour. Amer. Chem. Soc., xxiv, 362, 1902.

rous iron was determined by the method described by Pratt.* Water was estimated directly by a method devised by Prof. Penfield which will be described by him in a future number of this Journal. Boron was estimated by the Gooch method† with the modifications suggested by Penfield and Sperry,‡ and by Penfield and Foote.§ It was found necessary to add a little quartz to the first sodium carbonate fusion and to repeat the fusion of the residues at least twice in order to completely extract the boron. The large amount of calcium in the mineral seems to hold the boron quite tenaciously and only by observing the above precautions was it possible to extract all the boron and obtain correct determinations. A careful test was made for alkalies with but a negative result.

Results of Analyses.

Analysis No. I.—Axinite from Bourg d'Oisans. Specific gravity = 3·287.

	I.	II.	III.	Average.	Ratio.		
SiO_2	42·73	42·86	42·76	42·78	·713		÷ ·089 = 8·00
B_2O_3	5·84	6·40	----	6·12	·087		= 0·97
Al_2O_3	18·02	17·67	17·32	17·67	·171	·177	= 1·99
Fe_2O_3	·94	·90	1·15	·99	·006		
FeO	5·94	6·01	6·12	6·02	·083		
MnO	3·08	2·90	----	2·99	·042		
CaO	20·13	20·19	----	20·16	·360	·622	= 6·99
MgO	2·51	2·32	----	2·41	·060		
H_2O	1·37	1·44	----	1·40	·077		
				100·54			

Analysis No. II.—Axinite from Obira, Japan. Specific gravity = 3·028.

		Ratio.			
SiO_2	41·80	·696		÷ ·087 = 8·00	
B_2O_3	5·61	·080		= 0·92	
Al_2O_3	17·15	·166	·173	= 1·99	
Fe_2O_3	1·11	·007			
FeO	2·84	·039			
MnO	10·71	·150			
CaO	19·51	·348	·609	= 7·00	
MgO	·21	·005			
H_2O	1·22	·067			
	100·16				

* This Journal (3), xlviii, 149, 1894.
† Amer. Chem. Jour., ix, 23.
‡ This Journal (3), xxxiv, 220, 1887.
§ Ibid. (4), vii, 97, 1889.

Discussion of the Analyses.—In considering the results of the analyses it is first necessary to determine the rôles played by the boric oxide and the water in the mineral. The boric oxide in each analysis gives a simple and constant ratio with the SiO_2 and other oxides, that of SiO_2 to B_2O_3 being 8 : 1, and there seems to be no doubt but that it is always present in definite proportion and not as an isomorphous constituent replacing Al_2O_3. Concerning the water, the percentages in the two analyses are small, and the ratios of $SiO_2 : H_2O$ are 8 : 0·86 and 8 : 0·77, respectively, in both cases falling short of 8 : 1. Moreover, the ratios of SiO_2 to the protoxide bases, less the water, are not constant, being in the two analyses 8 : 6·12 and 8 : 6·23 respectively. If, however, the water is regarded as basic and isomorphous with the other protoxide bases, there are obtained such clear and exact ratios in both cases as to leave no doubt that this is the correct method of interpreting the results; moreover, the high temperature necessary to drive off the water and the study of other analyses, which will be quoted later, only serve to strengthen and reinforce this conclusion. Consequently in obtaining the ratios from the analyses and in deducing the formula of the mineral from them, the water has been considered as basic and as isomorphous with the protoxide group. According to this interpretation the two analyses give very satisfactory results, the ratios yielding almost exactly whole numbers. The ratios are as follows:

	SiO_2	B_2O_3	R_2O_3	RO
I	8·00	0·97	1·99	6·99
II	8·00	0·92	1·99	7·00

These ratios give the formula, which may be expressed as an orthosilicate, $R^{II}_7 R^{III}_4 B_2(SiO_4)_8$; R^{II} being chiefly Ca, with varying amounts of Mn, Fe, and Mg, and H_2 in small proportions. R^{III} is chiefly Al, but replaced always by a little Fe.

Discussion of Former Analyses.—The two analyses by Genth of the beautiful yellow axinite from Franklin seem to have only one defect, namely, that the water is given as loss on ignition; hence the percentage of MnO being high, it would be expected that the partial oxidation of this constituent would cause the results of the water determinations to be low. On studying his analyses they were found to give ratios closely agreeing with those demanded by the new formula with the exception of the protoxides, which were lower than required. It was decided, therefore, to make direct determinations of H_2O on the material in the Brush collection, the results being, as was expected, considerably higher than those given by Genth. The corrected analyses are given below and the ratios, as may be seen, are fully in accord with those given on page

196. Here, again, water is not present in sufficient quantity to give a ratio of $SiO_2 : H_2O = 8:1$, but when added to the protoxide bases the ratio of $SiO_2 : RO$ becomes nearly 8 : 7.

Analyses of axinite from Franklin, N. J., by Genth,* with corrected H_2O.

I. Crystalline Axinite.

			Ratio.			
SiO_2	42·77		·712		÷ ·089	= 8·00
B_2O_3	5·10		·073			= 0·82
Al_2O_3	16·73		·162	·168		= 1·88
Fe_2O_3	1·03		·006			
CuO	0·12		·001	·615		= 6·91
ZnO	1·48		·018			
MnO	13·69		·193			
MgO	0·23		·005			
CaO	18·25		·326			
H_2O	1·29	(corrected)	·072			
	100·69					

Water as given by Genth, 0·76.

II. Lamellar Axinite.

			Ratio.			
SiO_2	42·47		·707		÷ ·088	= 8·00
B_2O_3	5·05		·072			= 0·82
Al_2O_3	16·85		·163	·170		= 1·93
Fe_2O_3	1·16		·007			
PbO	0·09		....	·605		= 6·87
CuO	0·11		·001			
ZnO	1·53		·019			
MnO	13·14		·185			
MgO	0·26		·006			
CaO	18·35		·327			
H_2O	1·21	(corrected)	·067			
	100·22					

Water as given by Genth, 0·40.

Analysis of axinite from Bourg d'Oisans by Rammelsberg.†—From the analysis given beyond Rammelsberg derived the formula $HR^{II}_2R^{III}_2B(SiO_4)_4$, which differs but slightly from that obtained from the new analyses; thus by combining the hydrogen in Rammelsberg's formula with the bivalent bases and multiplying by two the formulas become identical. Rammelsberg's formula is the simpler of the two, but it cannot be accepted, as the new analyses never show sufficient hydrogen to satisfy it. Moreover in Rammelsberg's analysis the ratio of $SiO_2 : H_2O$ is 8 : 0·88, not quite 8 : 1, yet so nearly so that he

* Loc. cit. † Zs. G. Ges., xxi, 689, 1869.

was well justified in deriving his formula from the analysis. As shown below, by combining the hydrogen with the bases, the analysis also conforms very well with the new formula, the ratio being 8 : 0·88 : 1·97 : 6·83, or approximately 8 : 1 : 2 : 7.

Analysis of axinite from Bourg d'Oisans by Rammelsberg.

		Ratio.			
SiO_2	43·46	·724		÷ ·090	= 8·00
B_2O_3	5·61	·080			= 0·88
Al_2O_3	16·33	·161	·178		= 1·97
Fe_2O_3	2·80	·017			
FeO	6·78	·094	·615		= 6·83
MnO	2·62	·037			
CaO	20·19	·360			
MgO	1·73	·043			
K_2O	0·11	·001			
H_2O	1·45	·080			
	101·08				

*The analyses of Whitfield.**—Analyses were made by Whitfield, on material from Cornwall and Bourg d'Oisans. From the second of these analyses the formula, $BR^{III}_2R^{II}_4H_2(SiO_4)_5O$ was derived, which is quoted in a somewhat different form by Dana and Hintze. These analyses have been recalculated and the resulting ratios are given first according to Whitfield's formula and second according to the new interpretation. While the results are unsatisfactory in either case, they will be found to agree more closely with the new formula than with that proposed by Whitfield.

I. Axinite from Cornwall, by Whitfield.

		Ratio.			According to Whitfield.			According to new formula.	
SiO_2	42·10	·701	÷ ·070	=	10·00	or 10·00	÷ ·087	= 8·00	or 8·00
B_2O_3	4·64	·066		=	0·94	1·00		= ·75	1·00
Al_2O_3	17·40	·169	·188	=	2·68	3·00		= 2·16	2·00
Fe_2O_3	3·06	·019							
FeO	5·84	·081	·528	=	7·54	8·00		= 7·21	7·00
MnO	4·63	·065							
CaO	20·53	·366							
MgO	·66	·016							
H_2O	1·80	·100		=	1·43	2·00			
	100·66								

* This Journal (3), xxxiv, 286, 1887.

II. Axinite from Bourg d'Oisans, by Whitfield.

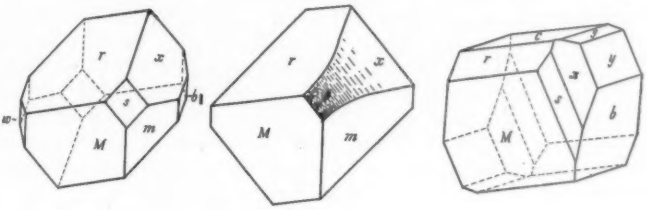
		Ratio.			According to Whitfield.			According to new formula.	
SiO_2	41·53	·692	÷	·069	= 10·00	or 10·00	÷·086	= 8·00	or 8·00
B_2O_3	4·62	·066			= ·95	1·00		= ·76	1·00
Al_2O_3	17·90	·173	·197		= 2·85	3·00		=2·29	2·00
Fe_2O_3	3·90	·024							
FeO	4·02	·056	·513		= 7·43	8·00		=7·36	7·00
MnO	3·79	·053							
CaO	21·66	·386							
MgO	·74	·018							
H_2O	2·16	·120			1·74	2·00			
	100·32								

Without question Whitfield's determinations of B_2O_3 are too low, and they would naturally be so if precautions were not taken to extract all of that constituent by repeated fusions with sodium carbonate and addition of silica.

Conclusion.—As the result of the foregoing investigation it would seem well established that axinite is a silicate in which the boron and the bivalent and trivalent bases are present in definite proportions. Expressed as an orthosilicate the formula is $R^{II}_7R^{III}_4B_2(SiO_4)_8$. The bases are chiefly calcium and aluminum, the Ca being always replaced in part by varying amounts of Mn, Fe, Mg and H_2, while a little Fe is isomorphous with the Al. A little hydrogen seems to be an unfailing constituent of axinite, and expressed as H_2O, the amount is remarkably constant in the analyses. As far as observed however, water is never present in sufficient quantity to satisfy the formula of Rammelsberg, and it seems best to regard it as basic, a rôle which it often plays.

Note on the crystals of axinite from Obira, Japan.—Two distinct types of crystals of axinite come from this locality. The first to be described is that of the material used in making Analysis No. II of this article. These crystals do not occur in separate individuals but in groups, made up of numerous crystals in nearly parallel position, rounding into one another. It is only at the edges of the groups that distinct crystal faces are seen. Measurements were made of these faces, and while as a rule the reflections obtained were poor, the following common forms were readily identified, developed about as represented by fig. 1: *b* (010), *m* (110), *M* ($1\bar{1}0$), *w* ($1\bar{3}0$), *s* (201), *x* (111) and *r* ($1\bar{1}1$). In reality the crystals are so grouped that only the faces shown in the upper right hand portion of the figure are to be seen. A characteristic feature of the crystals is a tendency for the *x* and *s* faces to round into one another, fig. 2 being an attempt to represent this. Still another tendency

is for the crystals to be grouped in nearly but not quite parallel position, all of the crystals curving in one direction corresponding to that of the zone $s - x$. The sharp edge between the x face and the M behind is usually prominently developed and forms the characteristic termination of the projecting crystals.



1 2 3

An entirely different type of crystal was observed on another specimen from the same locality and which is represented by fig. 3. Here in addition to the forms b, M, s, x and r already mentioned, the forms c (001), g (023) and y (021) were observed, and the large development of the zone c, g, y, b gives an unusual habit quite unlike that of ordinary axinite. All of the faces that were identified are represented in the figure.

It is with pleasure that acknowledgment is here made by the writer for the constant advice and assistance given him by Prof. S. L. Penfield, during the preparation of this article.

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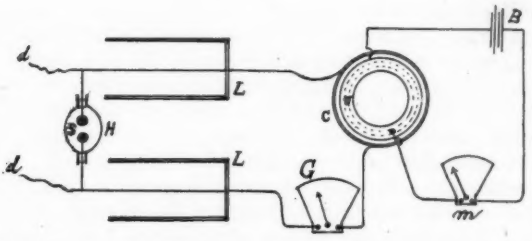
Yale University, New Haven.

ART. XIX. — *The Electrical Conductivity and Absorption of Energy in the Electrodeless Discharge ;* by BERGEN DAVIS, Ph.D.

THE current produced in gases by the electrodeless discharge is very intense but of short duration. This current produces, or is accompanied by, great ionization of the gas subject to the discharge. The object of these experiments was to measure the conductivity produced in gases by the discharge at various pressures. Great care was taken to keep the force producing the discharge uniform throughout the series of experiments. The method of doing this will be readily understood from the arrangement of apparatus, which was as follows:

1



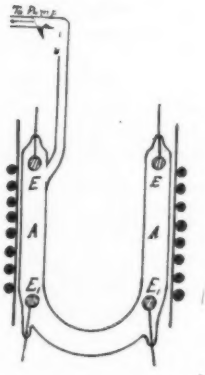
L L (fig. 1) are four large Leyden jars connected two in series and two in parallel. The inner coatings were connected to the spark gap S, and also by the leads *dd* to the terminals of the secondary of a large induction coil, which was driven by an alternating current of 40 periods per second. The outer coatings were connected to the terminals of the coil C surrounding the vessel V. A *hot wire* galvanometer, G, was placed in the discharging circuit for the purpose of regulating and comparing the amount of current passing through the coil C under various conditions. As the potential at which the spark passes and the period are constant, equal currents will represent equal potential gradients around the vessel. Upon the passage of the sparks at S, a strong discharge was produced in the vessel V. The conductivity produced in the gases by this discharge was measured by the galvanometer M, reading to 10^{-6} amperes, connected as shown in the figure.

The vessel V is shown in detailed section in fig. 2. The part of the vessel through which the discharge passed was the annular space AA, between two cylindrical vessels of different diameters placed one within the other, the edges being united at

the top. This space was 8^{mm} wide and 7^{cm} long. The outside diameter of the vessel was $6{\cdot}5^{cm}$. The electrodes were rings of aluminium, extending around at the top and bottom of the annular space. They are shown in section at EE and $E_{/}$ $E_{/}$.

The surface of each electrode was $7{\cdot}38^{sq\ cm}$ and the distance between them 6^{cm}. A constant difference of potential of 220 volts was maintained at these electrodes by the source B. At this potential no current passed between the electrodes except when the discharge was passing. This arrangement of the electrodes made the field of the E.M.F. of the electrodes perpendicular to that produced by the oscillations in the coil C. The component of ionic velocity under the first E.M.F. was independent

2



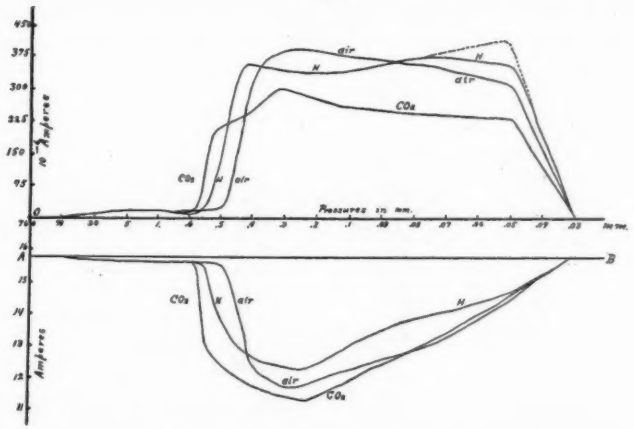
of that produced by the coil. It was found necessary to enclose the spark gap in an atmosphere of hydrogen in order to obtain a uniform discharging potential. The period of the alternating current driving the induction coil was 40 cycles per second, thus giving 80 sparks per second at the spark gap. This rapid succession of discharges gave uniform average readings on the two galvanomters G and M.

If the vessel V were removed from the coil C, on the passage of the sparks, the galvanometer G indicated a large current, being in these experiments 15·8 amperes.

The discharge was allowed to continue until the conditions became steady, and the galvanometer showed a steady deflection. When the vessel, properly exhausted, was put in the coil, the white electrodeless discharge appeared, and the *current* indicated by the galvanometer became very much less. In some cases the reading *dropped back* from 15·8 amperes to about 11 amperes. The amount of drop-back was depend-

ent on the degree of exhaustion and the nature of the gas in the vessel. The amount of heat developed was very great, showing that the gas within the vessel was absorbing a great deal of energy from the system. The *drop-back* of the galvanometer appears to be due directly to the absorption of energy by the gas. Prof. J. J. Thomson* has shown this effect by other methods: That if two coils be placed in series, the presence of a discharging vessel in one coil cuts down the current sufficiently to stop the discharge in the other; also that the discharge in an annular vessel prevents the effect

3



in another vessel placed within the annular one. This screening effect has recently been more fully investigated by E. Lecher.† The conductivity, as measured by the current passing between the electrodes E and E′, was found also to vary with the degree of exhaustion and the nature of the gas. The readings were taken as follows: The vessel was either removed from the coil or contained the gas at atmospheric pressure. The alternating current was turned on the induction coil and the sparks allowed to pass until a steady state was indicated by the galvanometer G. Then the vessel was placed in the coil and exhausted. The pressures were measured by a McLoud gauge. The two galvanometers and the pressure were read at the same time.

The curves obtained are shown in figure 3. The curves above the line represent the conductivities of air, hydrogen and carbon dioxide. The abscissæ are decreasing pressures and the

* Recent Researches. † Deutsche Phys. Ges., No. 13, 1902.

ordinates are conductivities in 10^{-6} amperes. The curves below the line AB represent the readings of the *hot wire* galvanometer. The ordinates taken *downward* represent the decrease of current in the coil caused by the discharge in the vessel. The conductivities, it will be observed, are quite small at large pressures. They rise suddenly to almost a maximum at the appearance of the white discharge.

In the case of air and carbon dioxide the conductivity decreases slightly with decreasing pressure until the pressure becomes ·05 mm, when the discharge suddenly ceases and the conductivity becomes zero. The conductivity in a gas may be expressed by

$$I = eN(V_p + V_n).$$

As the conductivity remains nearly constant, the number of ions must *decrease* with decrease of pressure, since the mean free path and also the ionic velocity increase rapidly with decreasing pressures.

The conductivity produced in carbon dioxide is considerably less than that produced in air. That for hydrogen is less for higher pressures and greater for lower pressures, than for air. The last reading for hydrogen at ·05 mm was not accurate as the discharge began to fail and so gave too small a value. The dotted curve is probably more nearly correct.

The curves below the line AB are dependent on the energy absorbed by the gas. It was quite noticeable that the vessel became hotter at the pressures at which the white discharge first appeared, than at lower pressures. The ordinates of the curves taken downward may be shown to be proportional to the energy absorbed by the gas, as follows: The Leyden jars with the discharging circuit and gas form a free discharging system, in which the current passing through the galvanometer G and the coil may be represented by

$$C = Ae^{-qt} \cos pt.$$

The coil C having a small resistance, the energy is dissipated in the gas and produces damping of the oscillations. The damping is proportional to the energy absorbed, for the galvanometer reads in amperes, while the energy is proportional to the square of the current, consequently:

$$\text{Readings} \propto \int_0^\infty e^{-2qt} \cos^2 pt\, dt$$

$$\propto \frac{2p^2+3q^2}{4q(p^2+q^2)}$$

$$\propto \frac{1}{q}, \text{ when either } p \text{ or } q \text{ is large compared to the other.}$$

The readings of the galvanometer are inversely as the damping or as the energy absorbed. It will be observed that the absorption varies with the density of the gas subject to the discharge; also that the absorption in all gases decreases with decrease of pressure.

It was found that if the vessel V were replaced by a single turn of wire whose ends were connected to a non-inductive ohmic resistance, then a definite resistance could be obtained that would produce the same drop-back of the galvanometer as the discharge in the gas. This gives a direct method of measuring the equivalent ohmic resistance of various gases at different pressures without the presence of electrodes.

It was my intention to determine these equivalent resistances, but an accident to the apparatus compelled me to abandon the experiments for that time.

As an illustration of the great absorption of energy and heating of the gas, I will mention the following experiment. A vessel was constructed having a thin platinum wire passing downward through the center. The passage of the electrodeless discharge heated the wire to incandescence in a few seconds.

These experiments were performed at the laboratory of Prof. E. Riecke in Göttingen, to whom I wish to make acknowledgments for the courtesies of the Physical Institute.

Cambridge, England.

ART. XX.—*Geological Structure of New Mexican Bolson Plains;** by CHARLES R. KEYES.

AMONG the most novel physical features which strike the eye of the traveler as he crosses New Mexico are the broad plains out of which the mountain ridges rise abruptly as volcanic islands out of the sea. These plains are twenty to thirty miles wide, often a hundred miles or more long, and at first glance appear nearly level. Closer aquaintance shows that they are basins, inclined towards the center and without marked drainage ways or drainage outlets.

With their usual keen appreciative distinctions of geographic features, the Spanish aptly call these inclosed plains "bolsons," meaning a purse. Of these plains, the writer who has brought their Spanish name into geographical usage says:

"These plains, or 'basins,' as they are sometimes called, are largely structural in origin. Bolsons are generally floored with loose, unconsolidated sediments derived from the higher peripheral region. Along the margins of these plains are talus hills and fans of bowlders, and other wash-deposits brought down by mountain freshets. The sediments of some of the bolsons may be of lacustral origin.

"It is essential, in both the geographic and the geologic discussion, to bear in mind the distinction between bolson plains and plateau plains. The plateau plains and the mountains are genetically related, the strata composing the one being bent onto or flexing out into the other. The bolson plains, on the other hand, are newer and later topographic features, consisting of structural valleys between mountains or plateau plains, which have been partially filled with debris derived from the adjacent eminences. The plateau plains are usually destructional stratum plains. The bolson plains are constructional detritus plains filling old structural troughs."†

A distinction between the plateau plains and the bolson plains is as important as it is real. But the statement that bolson plains are constructional detritus plains in structural valleys does not convey a correct idea of the phenomenon, and, as generally understood, the exact signification of the term structural as applied to the character of these valleys is very apt to be misinterpreted. In a carefully qualified sense the valleys occupied by the bolson plains might perhaps be considered structural valleys, but their history is very much more complex and very different from what might be suspected from casual observation.

* Read before the New Mexico Academy of Sciences, December 22, 1902.

† R. T. Hill: Topographic Atlas of United States, Folio 3, p. 8, 1900.

As the type of the bolsons, the Jornado del Muerto may be taken—that vast plain in southern New Mexico which from the time of the early Spanish explorers of the region up to 20 years ago was truly, as its name signifies, a "journey of death." This bolson is more than a hundred miles long and thirty miles wide. On the west are the Sierra de los Caballos and the Sierra Fra Cristobol, rising 3000 feet above the plain. On the east are the lofty Sierra San Andreas and Sierra Oscura. The railroad traverses the middle of the plain from north to south.

The mountain ranges are monoclinal blocks made up chiefly of Carboniferous limestones 1500 feet in thickness and resting directly on quartzites, granites and gneisses. The limestones of the eastern ranges slope westward; those of the western ranges dip eastward. To all appearances, the valley is a simple synclinal trough, the surface of which is covered by gravels. This is the impression that one gets from the train when passing through the region.

Closer examination of the rocks clearly shows that the beds do not lie in a simple syncline of which the mountain ridges are the upward protruding limbs. The strata lie at much higher angles than the general dips of a simple synclinal trough would require. Moreover, near the mountains, especially on the west side of the plain, is a belt three to four miles wide where the surface, so level when viewed from a distance, is found to be trenched by intricately ramifying canyons, often several hundred feet deep. The geological formations are here everywhere well exposed. While the general slope of the plain towards the center is only 2 to 3 degrees, the dips of the strata are often as high as 30 degrees in the same direction, and in places they are even vertical. On the beveled edges of the steeply inclined beds the plain-gravels are laid down; and also broad sheets of basaltic lava, the latter spreading out from numerous low cones.

The geological formations represented are essentially as follows:

Plains gravels (Pleistocene and Tertiary) 5 to 100 feet.
Yellow sandstones (Cretaceous) 4000 feet.
Red Beds (Upper Carboniferous) 1000 feet.
Blue limestone (Middle Carboniferous) 1500 feet.
Gray quartzite 50 feet.
Crystalline complex (exposed) 1000 feet.

A somewhat generalized geological cross-section of the Jornado del Muerto bolson is given below:

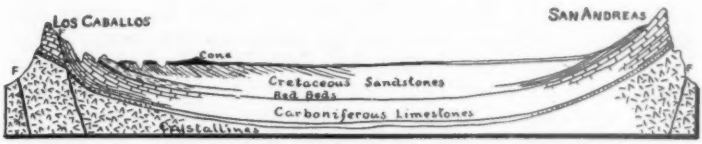


FIGURE 1. Generalized Cross-Section of the Jornado del Muerto.

The sequence of events in the region appears to be briefly as follows: In late Tertiary times, probably, the orogenic blocks began their tilting. Some crushing also took place and sharp local foldings were in evidence. During a pause in the uprisings, at or soon after the close of the Tertiary, the country was beveled off to the condition of a peneplain. Near the main crests of the primitive Los Caballos and San Andreas sierras, where the displacements were greatest, the Cretaceous and Red Beds were largely removed. With a new period of elevation lava flows spread out from various centers of activity, on the upturned beveled edges of the indurated beds. At the Caballo cone, a low volcanic hill on the top of the plains, a section shows the relationships of the various beds as given below:

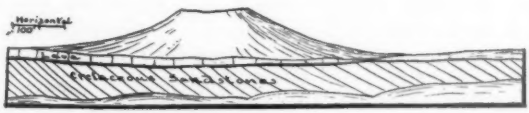


FIGURE 2. Caballo Cone, resting on Cretaceous sandstones.

Very recently a new cycle of stream cutting has been inaugurated. The Rio Grande, which flows southward on the west side of the Los Caballos range, has deepened into a valley 600 to 800 feet below the Jornado del Muerto. The side streams are rapidly cutting back into the great bolson. This period of erosion commenced since the volcanoes were active, for some of their flows are cut in two, and deep canyons mark the paths of the water-courses.

The gravels covering the Jornado are chiefly composed of crystalline pebbles—many of them apparently foreign to the region. The depths of the gravels covering the bolsons appear to have been greatly overestimated. One would naturally expect under the circumstances great thicknesses of detrital matter. The surprise has been the extreme thinness of the detrital materials covering these plains. In the Jornado del Muerto, the underlying Cretaceous rocks are exposed in many places, protruding through the few feet of gravels. Along the

main line of the Atchison, Topeka and Santa Fe railway the shallow cuts frequently expose the indurated bed-rock.

In the La Jara valley, 25 miles south of Santa Fe, where for many miles the plain is covered by gravels, where no indurated rocks are exposed, and where the beveled surface of the Cretaceous was thought to lie many feet beneath the present surface of the plain, drill-holes showed the gravels to be in places scarcely a dozen feet in thickness.

In the broad plain between the Ortiz and Sandia Mountains, east of Albuquerque, similar conditions prevail. At the Una del Gato, the relations of the gravels and the underlying rocks were found as represented in the accompanying cut:

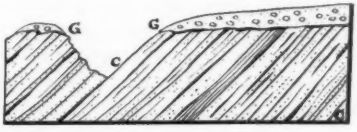


FIGURE 3. Beveled edges of Cretaceous sandstones, on which Bolson gravels rest, Una del Gato, New Mexico.

If any of these gravels attain the thickness ascribed by Shumard and others (500 feet), these measurements have nowhere been found even approximated to in the bolsons which have come under personal observation.

It must be concluded that the bolsons, or at least some of the principal ones, are not simple structural valleys, in the sense that that term is usually applied, though casual observation so indicates them. Neither is the detritus covering the bolsons so enormously thick as has been claimed.

State School of Mines, Socorro, New Mexico.

ART. XXI.—*Notes on the Marine Turtle Archelon. I. On the Structure of the Carapace, II. Associated Fossils;* by G. R. WIELAND.

IN my first contribution on the osteology of the huge turtle *Archelon ischyros* from the Fort Pierre Cretaceous of South Dakota, I figured (Plate VI, Reference 6*) the last cervical and first dorsal centra, together with the neurals and nine pairs of ribs, as found articulated in their approximately natural position, and associated with most of the other skeletal parts. Since then I have secured much additional material from which it will be possible to mount a quite complete skeleton. But as this will require an amount of time and museum resources equal, for instance, to that involved in the study or mounting of any Dinosaur yet placed on exhibition, a considerable period must elapse before any final contribution on this subject may be made. Hence it may be of some immediate service if the outline of the rib series in its entirety be given now, more especially since this is found to be of unusual interest.

Last autumn I secured near the Cheyenne River in South Dakota, among other material, an important additional skeleton of *Archelon*, in which the first rib, that articulating with the anterior end of the first dorsal centrum, is present. This makes it possible to complete the rib series, as shown in the accompanying text-figure.

In the absence of much careful work by a preparateur it would be difficult to indicate correctly the marginals in dotted line, because of the digitate or strongly serrate character of both the inner marginal borders, which vary much in different portions of the series. The illustration of the completed Carapace must for the present, therefore, remain in abeyance.

Description.—The *nuchal* is a large and handsome T-shaped element one meter in lateral width. I at one time provisionally regarded this bone as belonging to the plastron (7). This view was, however, in the opinion of Capellini supported by "neither embryological nor paleontological evidence" (2); Case in a manuscript note kindly submitted to me likewise opposed it. I am glad to find the complete evidence in accord with the views of these eminent authorities.

The *neuralia* are not of less area than in the Cheloninæ, but they are very thin, and are joined to each other and to the pleuralia by strongly marked, more or less imperfectly interlocking, sutural digitations. They are distinctly grooved on their median

* For convenience the references are grouped at the end of the article.

dorsal line, especially the first seven, this grooving being deepest and widest in the middle of each plate, from whence characteristic surface striations radiate. Regarding the number of neuralia I can only say that the boundaries of the first eight are distinct, but to make out clearly the relations and proportions in the pygal

1

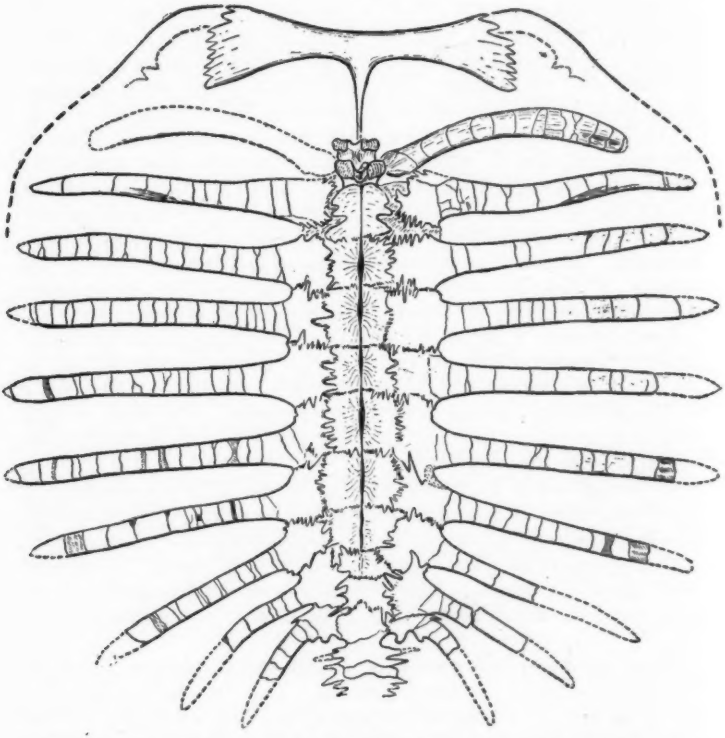


FIGURE 1.—*Archelon ischyros* Wieland. The nuchal, the anterior marginal border of the carapace, the neuralia, the pleuralia, and the complete rib series, with the last cervical and the first dorsal centra.—Dorsal view with nuchal set somewhat forward. (All the dorsal and sacral vertebræ are present and articulated in their natural position in the type specimen, on which the present figure is based, with the sole exception of the first rib.)
One-twentieth natural size.

region cannot now be readily done, in the absence of work by a preparateur. The final median plate shown in the figure is possibly represented as too long. Fortunately, however, the fine specimens I have secured promise when fully elaborated to

supply these and other important details in the osteology of these great turtles. Their discussion may, therefore, profitably await the complete restoration of the types which I later intend to give.

The *pleuralia* are greatly reduced in size, being of even less area than the neuralia, and fully as thin. They unite with each other and with the neuralia by loosely interlocking digitations. The pleural of the second rib in particular is thin and small, occupying only about an eighth of the entire rib length. (See figure.)

The *ribs* are very characteristic, the first being remarkable. The only specimen of this rib recovered is massive, and 74^{cm} in length, or fully three-fourths the length of the second rib, which is one meter long (see measurements). In the Cheloninæ (9) the length of the first rib, which is slender and reduced, is only about one-fourth that of the second. The first rib in *Archelon* is thus much more rib-like in general appearance than in all other turtles with which it may be directly compared, and must have extended out far enough for its distal end to rest in the marginal groove, as in the case of the ends of the other ribs. It is also quite possible that this rib was set even more obliquely to the vertebral column than is shown in the drawing. This point can later be determined. There is, however, no contact between this first rib and the first pleural, *Archelon* differing in this respect from all other turtles except *Dermochelys*.

The *second rib* is also more massive than in any of the Cheloninæ, this being in full accord with the reduced small and thin first pleural which it bears. In the case of the remaining pairs of ribs, which are free for about four-fifths of their length, the only character that need be mentioned now is the distal increase in vertical thickness. The second to the fifth pairs of ribs, inclusive, which are only about 2·5^{cm} in thickness where they emerge from beneath the pleurals, have near their distal ends a thickness of from four to five centimeters.*

Discussion.—In *Archelon*, as has been noted, the neuralia are strongly reduced in thickness, and the pleuralia in both thickness and area. In fact neuro-pleural reduction is greater than in the case of any other turtle known to possess all the

*In the figure the ribs are drawn in the nearly flattened position in which they were found, the first being the only one preserving the original curvature as in life. The width of the carapace hence appears accentuated. Nevertheless the general form of body was very robust. Indeed there appears to have been an almost Trionychian rotundity, with the nuchal lying more or less athwart the ends of the first pair of ribs (not the second as in the Trionychia), and projecting over from three to four of the cervicals as in *Dermochelys* and certain Pleurodirans, as *Pelomedusa*.

elements of the normal testudinate carapace. On the other hand, the ribs are more fully developed than those of any other fairly well-known turtle, not even excepting *Protosphargis* (1, 2) and *Dermochelys*. In the latter genus, however, the carapace being replaced, in as far as an outer bony shield is concerned, by a strong osteodermal mosaic, there is no necessity for a fully normal development of all the ribs, and such is not present, the anterior pair of ribs being in fact quite as much reduced as in the living Cheloninæ (9). In the latter the first rib, after affording support to the distal extremity of the scapula, flattens and ends against the inner surface of the very large first pleural. And this first pleural, which is in the simpler sense only an expansion of the second rib, is in turn strongly united by suture to the nuchal, the whole arrangement being one of compactness and great strength.

In the absence of a strongly joined nuchal and first pair of pleurals, efficient support for the scapular region of the shoulder girdle would be clearly obtained in one of two ways: Either there must be an increased size of the first rib, or additional strength must be secured by dermal thickening, with or without the development of osteodermal plates. And it is evident that if one of these conditions is found present it may be justly concluded that the other is absent, or but slightly developed. Hence, because of the great strength of the first rib in *Archelon* we may conclude that there was no unusual development of the outer covering of the carapace, whether leathery or of horn, and that there certainly was no osteodermal mosaic as in *Dermochelys*. The entire arrangement of the ribs, and of the supporting bones of the shoulder girdle region in *Archelon* thus forms an exceedingly clear example of *compensatory change*. There is also involved a return to early and primitive conditions. The Protosteginæ (9) as we know were distinctly pelagic, and, accepting the views of Baur and of Dollo, they are, in common with all the marine turtles, descended from ancestors with a normally developed carapace and plastron; while in the case of these ancestral forms we may be quite positive that the neuralia and pleuralia were of strong, and the ribs proper of minor development. Moreover, such forms must, of course, have been descended in turn from Theromeran (3) ancestors in which there was a fully normal rib development. In *Archelon*, therefore, the ribs may be considered as having regained a large and full size quite equal to that which must have characterized the early Theromeran ancestry of the Testudinates, although changed fundamentally in position with reference to the shoulder girdle. The neuralia and pleuralia, on the other hand, have undergone much reduction as compared with the marine turtles of to-day, the margi-

nalia remaining strong to robust. With reference to the first pair of ribs a word remains to be said. It would seem positively certain that in the ancestry of the Protosteginæ these ribs were much suppressed, but for the fact that in *Proganochelys*, as described by Fraas (5), the first pair of ribs has a wholly unique development. In this, the most ancient turtle known, the first rib is very large, and of peculiar form, the distal end being widely expanded, but in the vertical direction. In *Archelon*, however, the very slight distal expansion is lateral, and there does not appear to be much in common with this terrestrial Pleurodiran from the Keuper that would suggest even remote ancestral relationship.

The return to a primitive condition, as seen in the ribs above noted, has seldom been demonstrated. The only other well-authenticated instance of such return among the vertebrates within my ken is that of the canines of the camels as explained by Dr. J. L. Wortman. In the Eocene camels, the canines are small and incisiform; in the Oligocene and Miocene forms, these teeth assume an enlarged and normally caniniform pattern, while in the Pliocene and modern forms they again take on the primitive Eocene condition.

Although it does not as yet seem possible to me to correlate the carapacial changes just described directly with those most probably undergone by *Dermochelys*, it is believed that the example of compensatory skeletal change here recorded must be regarded as a highly interesting one.

Measurements of *Archelon ischyros*.

(*a*) *The First Rib.*

(From specimen about 12/13 the size of the type.)

	M.
Greatest length	·74
Circumference, 18·5^{cm} out from head	·225
Width half-way from head	·075
Width 50^{cm} from head	·09
Girth " "	·23
Depth of head in the dorso-ventral direction	·15
Least circumference about 30^{cm} from head	·21

(*b*) The length of the second, third, fourth, fifth, and sixth ribs, respectively, in the type specimen, is ·95, 1·01, 1·02, 1·02, and 1·01 meters. (The first rib would be 80^{cm} long.)

(*c*) The width of the first to tenth ribs of the type taken at their middle point is, respectively, (·08), ·075, ·075, ·078, ·075, ·07, ·065, ·06, ·055, and ·05 meters.

II.—*Associated fossils.*—With *Archelon ischyros* and *Marshii* there occurs in the uppermost 100 feet of the Fort Pierre (No. 4 Upper Cretaceous), as developed on the Cheyenne River, a series

of immediately associated forms of more than ordinary interest. In the first place, I have obtained in this same horizon well preserved toe bones of a Dinosaurian nearly of the form and nearly as large as those of *Claosaurus annectens*, which I shall figure later as *Claosaurus* (?) *affinis* sp. nov. And presumably from the same drift from a not far distant shore, I secured an exquisitely preserved new species of Palm stem, later to be described as *Palmoxylon cheyennense.*

Secondly, associated with these land forms are numerous Mosasaurs, a shark (a broad-toothed *Lamna*), a fish allied to *Beryx*, a Saurocephalodont, and the following invertebrates,—*Nautilus De Kayi* (very abundant in the matrix of one of the large turtle skeletons), *Placenticeras placenta, Scaphites nodosus, Emperoceras Beecheri* Hyatt, *Baculites ovatus* and *compressus* Say, *Callista Deweyi* M. and H., *Inoceramus*, etc., etc.—I hope again to call attention to this interesting assemblage, for it is not often that we are able to find in unquestioned association such well marked land and marine forms.

Yale University Museum, New Haven, Conn.

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ART. XXII.—*The Ionization of Water and of Phosphorus Nuclei. (Supplementary paper);* by C. BARUS.

1. IN the preceding paper,* I gave a revision of my views of the motion of the nucleus, showing that they admitted of an extension sufficient to include the exceptional and unexpected behavior of the water nucleus in the electric field, within the limits of potential used in my experiments.

I have since pursued the question into further detail and completed the computation for water nuclei and for phosphorus, so far as the data now admit. In equation (3) § 14 of the paper cited, I will put $K = k + UE/(r_2 - r_1)$, and proceed to find

$$1 - \epsilon^{-a} = 1 - \epsilon^{-\cdot 377 K l (r_2 + r_1)/V}$$

for a series of values of K, as follows:

$K = \cdot 001$	$1 - \epsilon^{-a} = \cdot 013$	$K = \cdot 2$	$1 - \epsilon^{-a} = \cdot 925$
$\cdot 01$	$\cdot 121$	$\cdot 4$	$\cdot 994$
$\cdot 05$	$\cdot 476$	$\cdot 8$	$1 \cdot 000$
$\cdot 1$	$\cdot 736$	$1 \cdot 0$	$1 \cdot 000$

This curve may be constructed in a chart in which K is the abscissa and $1 - \epsilon^{-a}$ the ordinate. In the exponent, $2r_2 = 2 \cdot 10^{cm}$, $2r_1 = \cdot 64^{cm}$, $l = 50^{cm}$, $V = 2$ lit/min. Meantime, one may note that if K and l vary reciprocally, the result remains unchanged. An inspection of the curve shows that the marked flexure occurs at about $K = \cdot 2$.

Now if the results for water nuclei (l. c., chart fig. 4) be compared with this curve, the two cases are seen to be quite similar and the marked flexure of the former occurs at about $E = 10$ volts as the electromotive force of the condenser. Since for water nuclei the specific velocity in the non-electric field is negligible, $k = 0$ and $K = UE/(r_2 - r_1)$. Hence if for coördination the points of marked flexure be regarded identical, $K = \cdot 2$, corresponds to $E = 10$ volts, roughly, and thus

$$U = \frac{\cdot 2 \times \cdot 73}{10} = \cdot 0146 \text{ cm./sec.}$$

2. If the velocity U of the nucleus be computed from the estimated radius R and the viscosity of the air, as in § 5, the data are, since $RU = \cdot 125 \times 10^{-6}$ in a field of volt/cm.

* This Journal (4), vol. xv, pp. 105–120, 1903. Cf. § 14. The notation is the same in both papers: E denoting the potential, C the effective capacity of the condenser; n the number of nuclei per cub. cm., e the charge of each, k their absorption velocity, U their combined ionic velocity; r refers to the radii, l to the length of the condenser and t is the current time.

$$R = 10^{-6\text{cm}} \qquad U = \cdot 125 \text{ cm/sec}$$
$$R = 10^{-5\text{cm}} \qquad U = \cdot 012 \text{ cm/sec}$$

if $l = 50^{\text{cm}}$.

Since $R = 10^{-5\text{cm}}$ is the superior limit of size* found from subsidence considerations, it appears that U is probably larger than ·012 cm./sec., if $l = 50^{\text{cm}}$, and hence this value of U computed purely from viscosity is in agreement with the value of U just deduced from purely electrical data.

Furthermore, the order of size and the velocity deduced are compatible with my work on the structure of the nucleus, $k = \cdot 001$ to ·03 being here the specific velocities in the absence of the electric field. Hence k is small compared with $UE/(r_2 - r_1)$, the condition supposed.

3. The behavior of the phosphorus emanation is next to be treated. Here the value of k, or the specific velocity of the nucleus in a given cardinal direction, was found by direct experiments to be $k = \cdot 3$ cm./sec. Hence the value of the exponential factor, $1 - \epsilon^{-a}$, even when $E = 0$, is about ·96 and may therefore be neglected as experiment showed. Consequently in this case

$$-(dE/dt)/E = \frac{16 \cdot 7\, n_0 e V}{C(r_2 - r_1)} \frac{U}{k}$$

as heretofore stated, where, moreover, for want of direct knowledge, $U = k$ was assumed. This is virtually supposing, since here $RU = \cdot 125 \times 10^{-6}$, that the size of the phosphorus nucleus is $R = \cdot 42 \times 10^{-6\text{cm}}$, a datum which, provisionally at least, is admissible.

If the nuclei are larger than this, the factor U/k must be evaluated in computing n_0 from $2 \cdot 3\, a = (dE/dt)/E$, as

$$n_0 = (k/U)(2 \cdot 3\, a C(r_2 - r_1))/16 \cdot 7\, e\text{V}.$$

Now it is suggestive to observe that the datum for n_0 for tubular condensers was always *low* as compared with the same datum for plate and for spherical condensers.

Thus from plate condensers, $n_0 = 33 \times 10^4$
from spherical condensers, $n_0 = 39 \times 10^4$
from tube condensers, $n_0 = 8 \times 10^4$

I attributed this with some misgiving wholly to want of saturation in the latter case since an influx tube is inevitable.

But in the value of n_0 for plate and spherical condensers the value of k does not enter, and the results depend simply on U. Hence what was supposed to be wholly undersaturation was probably, in part, the neglect of the factor k/U. Put, there-

* There would be coincidence for $R = 8 \cdot 6 \times 10^{-6}$.

fore, $n_0 = 2{\cdot}3aC(r_2 - r_1)/16{\cdot}7\,eV$ as the approximate equation for the nucleation at the influx pipe of the tubular condenser, while

$$n_0' = n_0 k / U$$

is equal to the datum found for plate and spherical condensers. Hence if $k = {\cdot}3$ cm./sec. for the phosphorus emanation, a lower limit of U, is

$$U = kn_0/n_0' = {\cdot}3 \times 8/36 = {\cdot}067 \text{ cm./sec.}$$

In other words, the velocity of the phosphorus nuclei in the unit (volt/cm.) field is about ·07 cm./sec. The radius of the phosphorus nucleus will then be

$$R = {\cdot}125 \times 10^{-6}/{\cdot}067 = 1{\cdot}9 \times 10^{-6} \text{ cm.},$$

i. e., about 4·5 times larger than the value obtained under the assumption of $U = k$.

4. The results thus found for phosphorus nuclei make it necessary to reopen the computation of n for plate and spherical condensers. The assumption formerly made was $U = k$, as a normal case and in the absence of available guidance. It is well, therefore, to summarize the equations used as follows:

For plates, $-(dE/dt)/E = A\,Un_0 e/Cx\epsilon^{ax/A}$, where A is the area, x the distance apart, a the linear edge of the plates. Herefrom, if $U = 1$ cm./sec. $n_0 = 33 \times 10^4$.

For tubes, $-(dE/dt)/E = 16{\cdot}7\,VUen_0(1 - \epsilon^{-a})/(r_2 - r_1)kC$, whence if $U = k$, $n_0 = 8 \times 10^4$.

For spheres, $-(dE/dt)/E = 4\pi e Un_1/CR$, where R is the radius, n_1 the nucleation for radius $1^{\text{cm.}}$. Herefrom, $n_1 = 39 \times 10^4$, if $U = 1$ cm./sec.

The value of U for the phosphorus emanation has been estimated anew in the preceding paragraph as about ·07 cm./sec. Consequently these equations all need corresponding corrections. Since n_0 varies as $1/U$, the estimated diminution of U increases n, $1/{\cdot}07 = 15$ times. Thus the number of nuclei computed for $U = {\cdot}07$ cm./sec., and for complete saturation of the phosphorus emanation will be

from plates,	$n_0 = 4{\cdot}9 \times 10^6$
tubes,	$n_0 = 5{\cdot}4 \times 10^6$
spheres,	$n_1 = 5{\cdot}8 \times 10^5$

results which contain the most careful revision of the subject which I have been able to make. Note that in computing U for phosphorus, l the condenser length does not occur as the exponential term vanishes. The datum $k = {\cdot}3$ cm./sec. was found by direct experiments with the steam tube (Exp. with Ion. Air, Chap. 3). The ratio k/U follows from comparison of tube with plate and spherical condensers. The method here

is then independent of the one used for water nuclei, the latter being not applicable to phosphorus at all. It is obvious, however, that in the light of the experience now gained, a complete repetition of the experiments is desirable, since in tubular condensers there is necessarily undersaturation, the effect of which is to decrease n_0.

Unfortunately the coronas are not as directly available with the phosphorus emanation as with water nuclei; for while the condenser determines the nucleation of the air immediately after it has passed over phosphorus, condensation can only be produced in vessels in which the nucleation is either dilute (small charge of emanation added to a large bulk of air), or is stale, while the initial coronas are mere fogs. Thus the procedure carried out for water nuclei fails for phosphorus, but I shall show in a succeeding paper how it may be supplemented, and that the data of a purely optical method are of the order of those just found from a purely electrical method.

5. The question now arises whether the effect of a field in removing nuclei more or less completely may be explained. If $U = e/6\pi\mu R$, the current will be, per square centimeter,

$$i = \frac{E}{x}\,\frac{ne^2}{6\pi\mu R}$$

where E/x is the potential gradient. For the same current in the unit field, $ne^2/\mu R = ne\,V/\mu =$ constant, or the number of nuclei needed will depend inversely on the square of their charges and directly on their radii; or in a given medium will depend inversely on the energy of their charge.

The question takes rather a different form, inasmuch as it is of interest to know how the number of charges removed by the field compares with the total number present in and added from without to the medium during this interval. The case may be worked out for the cylindrical condenser, as above.

If time losses of nuclei and charges other than are due to absorption at the walls of the vessel be ignored, and if n nuclei are present at the section $l = 0$ and n at the section l of the condenser,

$$n = n_0 \epsilon^{-\frac{2\pi k l (r_2 + r_1)}{16 \cdot 7\, V}}$$

In the absence of the field this equation determines the spontaneous loss of charges whether the nuclei are spontaneously lost or not; but in the presence of a field the charges are more rapidly removed because of the added velocity imparted to the nuclei. Moreover for water nuclei, k may usually be neglected in comparison with $UE/(r_2 - r_1)$. In other words, $K = UE/(r_2 - r_1)$, and

$$n/n_0 = 10^{-\cdot 163Kl(r_2+r_1)/V}$$

is the relative nucleation at the right section l of the tube condenser.

The following table contains results for a number of typical cases. For phosphorus, if perfectly fresh, $k = \cdot 3$ cm./sec., while the velocity of the nucleus in the unit field is $U = \cdot 067$ cm./sec., as a lower limit.

TABLE I.

Number of nuclei (n/n_0) in successive right sections of the tubular condenser, length $l = 50^{cm}$, diameters $2r_2 = 2\cdot 10^{cm}$, $2r_1 = \cdot 64^{cm}$. $V = 2$ liters/min. E in volts, k in cm./sec.

	Ratio n/n_0, if			Ratio n/n_0 if $U = \cdot 015$ cm./sec., and			
l	$k = \cdot 3$	$k = \cdot 03$	$k = \cdot 003$	$E = 10$	$E = 50$	$E = 100$	$E = 1000$
0	1·00	1·00	1·00	1·00	1·00	1·00	1·000
1	·93	---	---	·95	·76	·59	·005
5	·67	---	---	·77	·26	·07	---
10	·46	·93	·99	·60	·07	---	
20	·21	·86	·98	·36	---		
30	·09	·79	·98	·21			
50	·02	·67	·96	·08			

For the case of water nuclei* if obtained from solutions of concentration

1 %	·01 %	·0001 %	
$k = \cdot 0008$	·0013	·03	cm./sec.

while $U = \cdot 73/l$ cm./sec., where l the effective condenser length has been taken. The table takes the excessive value $l = 50$.

Consequently the first part of the table shows the relative nucleation in different sections of the condenser when k has the values stated. The first column would apply to fresh phosphorus nuclei, the last two for water nuclei obtained from different dilute solutions in the absence of an electric field. Most of the phosphorus nuclei should vanish, but the water nuclei are but slightly reduced on leaving the condenser. One may note the small velocity of current $V = 2$ liters/sec.

The second part of the table shows the case for water nuclei when the core of the condenser has different potentials, E, for the assumed velocity, $U = \cdot 015$ cm./sec. in the unit electric field, since k may here be neglected. If $l = 5^{cm}$, the column for 10 volts would apply at 100 volts, etc. It is seen that the charges of nuclei are speedily absorbed while, from the evidence given by coronas, the number of nuclei falls off but slightly.

6. It thus becomes a question of crucial importance to ascertain whether the charges are actually lost to a few per cent in

* This Journal (4), xiv, p. 225, 1902.

the first few centimeters of the condenser, or very near the influx tube. A condenser was, therefore, constructed the length of which could be varied by placing earthed tubes, $2r_2 = 2{\cdot}10^{cm}$ in diameter and of different lengths, $l = 60, 30$, and 15^{cms}, around a fixed charged insulated core, $2r_1 = {\cdot}64^{cm}$, concentrically with the usual precautions.

Table II shows the results in which the insulation of the condenser was determined before and after each measurement with the nucleated medium. The condenser lengths 60 and 15^{cms} are inserted as a sufficient contrast.

TABLE II.

Effect of length of tubular condenser. $dV/dt = 1{\cdot}9$ liters/min.

		Leakage ds/dt			
Length	Charge at	Before	During nucleation.	After	Current $i \times 10^{11}$ amperes.
60^{cm}	+80 volts	·02	·42	·00	1·07
15^{cm}	+80 volts	·05	·45	·00	1·12
15^{cm}	+80 volts	·00	·47	·02	1·20
15^{cm}	−80 volts	·03	·26	·00	·62

It is seen that the current is certainly quite as large, *caet. par.*, when the length of the tube condenser is 15 as when it is 60^{cm}. It is actually larger at 15^{cms} due to the gradual enlargement of the needle holes in the lead jet* whereby fresher nuclei are conveyed into the condenser. The current for positive and for negative charges have the usual relation to each other.

The experiments showed another interesting fact already pointed out elsewhere, that the current, ds/dt, increases as the water level in the receiver rises or as the discharge into the condenser is fresher. One naturally inquires what the maximum charge of each nucleus would be if there were no conveyance tube. In the present installation this jet was unable to charge the condenser, the charging current being less than 10^{-12} amperes, about of the same order as the leakage.

One may conclude, therefore, that the loss of charge per minute, i. e., the current radially traversing the condenser, is practically independent of its length if the latter exceeds a few centimeters, for the air current and width given. All but a few per cent of the charge are lost in the first few centimeters ahead of the influx tube of the condenser. The experiments are thus in keeping with the surmize of Table I.

7. *Summary.*—In case of water nuclei it was found from coincident electrical current graphs, $Ul = {\cdot}73$, and if the con-

* The fine holes clog with lead hydrate when the jet is left standing in a damp atmosphere, and the obstruction is gradually removed by the friction of the water. Old jets long unused, therefore, show small electrical currents as compared with new jets.

denser length is $l = 50^{cm}$, the combined velocity of the charge in the unit field is $U = \cdot 015$ cm./sec.

From considerations relating to the viscosity of the medium it was found that $RU = \cdot 125 \times 10^{-6}$ and if U is taken equal to $\cdot 015$ cm./sec., as just stated, $R = 8 \times 10^{-6}$ follows for the radius of the water nucleus. A superior limit $R = 10^{-5cm}$ would follow from subsidence considerations.

From direct experiments on the diffusion of nuclei (this Journal, xiv, 225) for solutions of initial concentrations of $\cdot 01$ per cent and $\cdot 0001$ per cent, $k = \cdot 0013$ and $\cdot 03$ cm./sec., respectively. These values of k are necessarily much smaller than $UE/(r_2 - r_1)$, and the data are confirmatory.

From measurements of the apertures of coronas, $n = 10^3$ to 10^4 nuclei per cubic centimeter.

In case of phosphorus nuclei, $k = \cdot 3$ cm./sec. for the velocity of the nucleus in a given direction, and in the absence of the electric field was found directly from experiments with the steam jet and absorption tube.

In the electrometer work with this emanation, $U = \cdot 07$ cm./sec. and $R = 1 \cdot 9 \times 10^{-6cm}$ follow from a final comparison of the nucleation data n_0' for plate or spherical condensers (full saturation) with the nucleation of tube condensers, n_0 (deficient saturation), since here $U = kn_0/n_0'$. Thus U increases with n_0, and if n_0, by specially devised methods, is increased to $2n_0$ (which has been possible), $U = \cdot 14$ cm./sec. and $R = 10^{-6cm}$ follow.

Finally the nucleation for complete saturation was $n_0 = 5 \times 10^6$ nuclei per cubic centimeter; but if U can be raised to $\cdot 14$ cm./sec. as just stated, $n_0 = 2 \times 10^6$. The nucleation of the saturated phosphorus emanation thus exceeds a million per cub. cm. at the surface of the phosphorus. It is, therefore, larger than I at first made out, and in a subsequent paper I shall show that the same order of values follows from the purely optical experiments made with coronas.

It is because of this general consistency in the results of experiments so widely different in character, that I venture to adhere to the essentials of my old hypothesis.

Brown University, Providence.

ART. XXIII. — *On a Method of Demonstrating Newton's Colors by Transmitted Light;* by H. N. DAVIS.

IT is well known that if white light be passed through a thin film, part of it will be reflected twice within the film and will cause interference and color phenomena. These are usually very faint because the amount of light that is thus reflected is so small as compared with what passes directly through, as to have but a slight effect. If, however, the same wave-front be passed through a uniform series of films, successive portions of certain colors should be blotted out in each film, while other colors which get through the first film without interference, should emerge from each of the other (similar) films without interference, and the color effect should be cumulative,

At the suggestion of Professor Barus, these surmises have been empirically verified, and excellent results obtained. If a number of wire rings of the same size be mounted in parallel planes, and dipped together into a soap solution, their planes being kept perpendicular to its surface, a suitable series of films results, through which light can be passed and caught on a sheet of paper, showing the desired phenomena very beautifully. Since each film, under the action of gravity, is a very thin wedge, the colors are in horizontal bands, appearing first at the top (where the wedge is thinnest) and moving slowly down across the field as the films evaporate, to be succeeded by other bands of lower orders. Indeed good films will often hold until two-thirds of the field is colored with the yellowish-brown of the first order. And if the paper be replaced by a good lens, and the colors projected on a large scale upon a suitable screen, they can be strikingly demonstrated to a class. Some of the effects obtained in this way are most magnificent, even rivaling the best of our autumn sunsets, until it is only with reluctance that one concedes the essential dissimilarity between the two phenomena. In practice, the important thing seems to be uniformity in size and alignment in the set of rings. I have found it convenient to make them some $5{\cdot}5^{cm}$ in diameter, using galvanized iron wire ($d=1{\cdot}2^{mm}$) and forming each around a pattern of wood or metal, the ends being twisted together into a sort of handle. Such rings can be temporarily strung on three rods, notched at appropriate intervals to insure parallelism in the planes of the rings, while the "handles" are being clamped between two pieces of soft wood. The rings should be at least a centimeter apart to avoid cylindrical and irregular films, and from fifteen to thirty are sufficient. A tin

trough of such dimensions as just to admit the set facilitates the dipping.

During the course of this experiment, before the films have become thin enough to show colors, certain other phenomena of a circulatory character are very noticeable. These may be studied most easily in the projected image of a single film, and for observations on conditions immediately after formation, it is convenient to support a ring on the shorter branch of a J-shaped "handle" and to fix it permanently in the focus of the projecting lens, a narrow trough being raised so as to submerge the ring when necessary. The moving images are of two kinds, one corresponding to pear-shaped air-bubbles running up at the sides of the film, the other to spheroidal drops running down through the middle. These sets of images are always of opposite colors, and if, under given circumstances, the air-bubbles show white and the drops black, then moving the film some 4^{cm} away from the lens will reverse the colors, the bubbles showing dark and the drops white. From this it is evident that the latter act as convex lenses with real foci (bright spots) some 2^{cm} in front of the film, while the bubbles are concave lenses with virtual foci 2^{cm} behind it.

These air-bubbles require but little explanation, but the drops are more interesting. The happenings in a typical film (dipped at a time $t=0$) are as follows: At first its image is clear, but almost immediately a few large drops appear at various parts of the film and begin to descend. These "wanderers" are much larger than their successors ($d=0{\cdot}5$ or $0{\cdot}6^{mm}$) and their number varies from one to a dozen, being largest when a preceding film has dried on the ring and has not been removed. At $t=1$ sec. a "skirmish-line" has formed about a third of the way down, above which line the film is closely dotted with drops. This travels down in the film about as fast as do the color-bands later, reaching the bottom at $t=$about 8 sec. The drops in its front rank are usually small, but a half a centimeter behind come the largest of the "ordinaries" ($d=0{\cdot}2$ to $0{\cdot}3^{mm}$) and after these a succession of smaller ones until (at $t=60$ to 100 sec.) the film begins to show colors and great viscosity is noticeable. The size of the average drop is some $0{\cdot}2^{mm}$ and, roughly speaking, the size of those passing a given point decreases as t increases. The velocity of descent varies from 0 to 7^{mm} per sec. (that of the wave front averaging $5{\cdot}7^{mm}$ per sec.) and is greater (1) for large drops, (2) for drops near the bottom of the ring and (3) at times corresponding to small values of t, but, if other things are equal, is nearly the same at all points in the same horizontal line. A number of observations gave an empiric formula $v^2=2p\,(y-q)$ (y being the distance from the top of the ring, and p and q functions of t, the former decreas-

ing—very rapidly at first—and the latter increasing as t increases). This formula is, of course, a rough approximation, but analogies between it and $v^2=2gs$ are very interesting. These "drops" are not simply bulges due to variations in the surface tension of a film (for similar phenomena appear in the image of a thin glass cell filled with solution) but are little globules floating in the liquid, composed of a more concentrated solution with greater density and refracting power, and with a surface tension with respect not only to air but to the rest of the solution; though the process by which such definitely separated globules are formed is not quite clear.

It is not unlikely that further study of the nature, form, and velocity of such descending masses, both in films and in thin cells (where they are spheres and the surrounding medium is stationary) may lead to a method of investigation not only of changes in viscosity due to evaporation but possibly also of the problems of surface-viscosity, in connection with which further knowledge would be very desirable.

Brown University, Providence, R. I.

ART. XXIV.—*Note on the Amphibole Hudsonite previously called a Pyroxene;* by S. WEIDMAN.

DESIRING to make a comparison of the microscopic appearance of the mineral hudsonite with a certain pyroxene occurring in the quartz-syenite of central Wisconsin, the writer requested of and received from Professor S. L. Penfield of Yale University sufficient mineral for this purpose. The material sent the writer is a portion of the specimen* sent from Cornwall, Orange County, New York, to Professor Brush in 1853 by S. R. Horton, and which is the same as that sent by the latter to Professor L. C. Beck† about ten years earlier, from which the original description of the mineral hudsonite in 1842 was made.

Thin sections of hudsonite having been made and placed under the microscope, it was seen by the prismatic cleavage of 56° and 124° and by the optical properties of low birefringence, strong pleochroism and absorption, that this mineral is an amphibole, and not a variety of pyroxene as it has always been supposed. Cleavage fragments of the mineral measured by a hand goniometer also readily showed the prismatic cleavage to be that of amphibole. Since this mineral has been listed as a member of the pyroxene group for nearly sixty years in all works on mineralogy, it was thought a brief statement concerning its history and character would be of interest.

History of Hudsonite.—The name hudsonite was proposed by Dr. Louis C. Beck‡ for a new species of mineral, in 1842. The description by Dr. Beck is as follows: "Color, black, often with brownish tarnish. Streak, green. It occurs massive, exhibiting one very perfect cleavage like some varieties of pyroxene. Luster vitreous to resinous. Opaque. Hardness from 4·5 to 5; specific gravity 3·5. Alone before the blowpipe it fuses with effervescence into a black bead, which is attracted by the magnet. This mineral, which is proposed as a new species, was found by Dr. Horton in a vein of quartz in the town of Cornwall, Orange County. Its composition, according to my analysis, is as follows:

Silica	37·90
Oxide of iron	36·80
Alumina	12·70
Lime	11·40
Magnesia	1·92
	100·72"

* This Journal, xvi, 369, 1853.
† Nat. Hist. of New York, Part III, Mineralogy, p. 405, 1842.
‡ Loc. cit.

Hudsonite was later classed by Dana* with pyroxene, although there is no record of a further examination of it. Dana's classification was accepted by Beck† in 1850.

Brewer‡ in 1850 also made an analysis of this mineral with the following result:

SiO_2	36·94
Al_2O_3	11·22
Fe_2O_3	trace
FeO	36·03
MnO	2·24
CaO	12·71
MgO	----
	99·14

The density of the mineral, according to Brewer, is 3·43 to 3·46.

In 1853 Smith and Brush§ made two new analyses of the hudsonite, the mineral being supplied by S. R. Horton and being the same, as already stated, as that sent by him to Professor L. C. Beck. The analyses of Smith and Brush are as follows:

SiO_2	39·30	38·58
Al_2O_3	9·78	11·05
FeO	30·40	30·57
MnO	·67	·52
CaO	10·39	10·32
MgO	2·98	3·02
K_2O	2·48	4·16
Na_2O	1·66	
Ignition	1·95	1·95
	99·61	100·17

The presence of 1·95 per cent of water (ignition) in the analyses of such careful analysts as Smith and Bush indicates that the mineral analyzed was amphibole rather than pyroxene. The analyses of Smith and Brush are more nearly complete than those of Beck and Brewer, and taking this into consideration, it is seen that the four analyses clearly confirm one another. No other work on the mineral hudsonite, to my knowledge, has been done since that of Smith and Brush in

* System of Mineralogy, 2d ed., 1844.

† Third Ann. Report of the Regents of the University of New York on the condition of the Cabinet of Natural History, p. 131, 1850.

‡ Liebig-Kopps's Jahresberichte, p. 712, 1850.

§ This Journal, xvi, 369, 1853.

1853. This was long before the microscope came into use, and hence nothing was known concerning its optical properties.

Description of the Amphibole Hudsonite.—The macroscopic appearance of the hudsonite closely agrees with the original description by Beck. Its color is black to brownish black. Luster, vitreous. Besides the very perfect prismatic cleavage of 54° to 56°, * there is a well developed transverse parting with distinct twinning lamellæ parallel to the parting, which is identical in character and position with that described by G. H. Williams† in actinolite. This parting or pseudo-cleavage is a marked feature of the hudsonite. On the orthopinacoid it forms striations normal to the prismatic cleavage, and on the clinopinacoid the striations make an angle of about 76° with the prismatic cleavage. These structure planes are common in pyroxene, where they are considered to be in the plane of the basal pinacoid. It was very likely this pronounced parting which led Beck to liken this mineral to pyroxene in his original description.

Under the microscope the mineral is seen to be free from alteration, but it contains a few small areas of limpid quartz and a very slight infiltration of extraneous material in the older fractures. Following Tschermak and Dana, the plane of parting and of twinning lamellæ above noted is considered the basal pinacoid (001) in order to make it correspond with the similar structural plane in pyroxene, instead of considering it in the plane of the orthodome ($\bar{1}01$) in accordance with other text-books. A thin section which was cut as near as possible in the plane of the clinopinacoid showed the transverse parting planes to form an angle of about 76° with the prismatic cleavage, and thus the slide was cut sufficiently near the plane of the clinopinacoid to furnish the extinction angle of the hudsonite. A series of measurements showed the plane of extinction to be about 9° from the vertical axis in the obtuse axial angle β. This axis of elasticity, being apparently less than the one normal to it in this plane, it is considered the c axis, and hence $c \wedge \dot{c} = + 9°$. The optic angle and character could not be satisfactorily determined. The pleochroism is pronounced and absorption strong: a = light olive green, b = green with slight tinge of yellow, c = green with slight tinge of blue. Absorption, $c > b > a$.

While transverse parting in actinolite and common green hornblende parallel to the base (001) has been observed‡ by a number of writers, twinning lamellæ parallel to this plane apparently

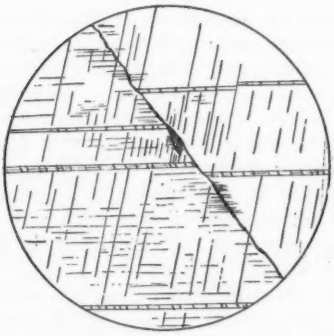
* Prof. Penfield has since measured the angle of the prismatic cleavage with a reflection goniometer and found the values $m \wedge m = 55° 31'$.

† This Journal, xxxix, 352, 1890.

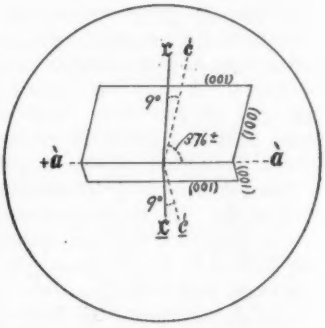
‡ See Zirkel, 2d ed., i, 300.

has not been so commonly noted. In the hudsonite the twinning lamellæ vary considerably in width, having a maximum breadth of 0·02^{mm} in the several sections examined. The larger lamellæ are usually continuous across the section, while the smaller ones often thin out into mere lines or end abruptly at a fracture. The appearance of the twinning lamellæ in a portion of a slide parallel to the clinopinacoid (010) is shown in figure 1. The short and thin lamellæ or parting planes are concentrated along the fractures, and thus bear witness that the twinning and parting, like the fractures, have a secondary dynamic origin. The larger and more continuous lamellæ are probably connected with larger fractures in the mineral not seen in the slide. Figure 2 represents the optical orientation and its relation to the structural planes of prismatic cleavage and basal twinning and parting as seen in the plane of the clinopinacoid.

1



2



The occurrence of transverse twinning lamellæ and parting planes in amphibole, like those described in the hudsonite, corresponding to similar structure planes in pyroxene, where they are considered parallel to the basal pinacoid, is only another instance showing the wisdom of the method of giving the same symbols to these analogous planes in both groups as first suggested by Tschermak in his Lehrbuch der Mineralogie, in 1884, urged by a number of writers, and finally fully adopted by Tschermak and Dana in their text-books. The several cogent reasons for this change were well stated by Mügge* and Williams† a number of years ago and need not be repeated here. Because of this change adopted in the orientation of amphibole so as to correspond throughout with pyroxene, there is necessarily a lack of uniformity in literature in describing the relations of

* Neus. Jahrb. f. Min., 1889, i, 244. † This Journal, xxxix, 356, 1890.

the optical axes to the crystallographic orientation of the amphiboles. According to Dana and Tschermak, for instance, the axis of least elasticity in amphibole, as in pyroxene, lies in the obtuse axial angle β, whereas according to Zirkel, Rosenbusch, Groth, Des Cloizeaux, Hintze and others who consider the basal pinacoid (001) of Tschermak and Dana the orthodome ($\bar{1}01$), the axis of least elasticity lies in the acute axial angle β. For the sake of greater clearness, therefore, it would seem to be advisable, when the axial angle and the axes of elasticity are referred to, for each writer to state which of the two orientations is adopted.

The writer is indebted to Mr. J. L. Nelson, graduate student in geology, assisted by Professor W. W. Daniells, professor of chemistry in the University of Wisconsin, for the following analysis of the hudsonite :

SiO_2	36·86
TiO_2	1·04
Al_2O_3	12·10
Fe_2O_3	7·41
FeO	23·35
MnO	0·77
CaO	10·59
MgO	1·90
Na_2O	3·20
K_2O	1·20
H_2O at 110° C.	0·70
H_2O at red heat	0·60
	99·72

This analysis differs from that made by Smith and Brush in showing the presence of 1·04 per cent of TiO_2 and 7·41 per cent of Fe_2O_3. It is probable that neither of these constituents were sought for by Smith and Brush, the TiO_2 being weighed with the SiO_2, and the whole of the iron being considered as FeO. The few inclusions of quartz in the hudsonite are sufficient to cause an appreciable variation in the determination of the amount of SiO_2. With this explanation the analysis of Smith and Brush may be considered to agree very closely with that made by Nelson and Daniells. From the above analysis and those previously made it will be seen that the hudsonite does not correspond in composition with the common amphiboles, but is closely related to barkevikite, hastingsite, and similar alkali-amphiboles. For the sake of comparison the hudsonite is grouped with some of the amphiboles near it in composition in the following table :

	I	II	III	IV	V	VI	VII	VIII
SiO_2	43·85	42·00	36·86	42·46	38·41	35·42	34·18	36·78
TiO_2			1·04			1·34	1·53	
Al_2O_3	4·45	12·00	12·10	11·45	17·65	8·89	11·52	15·13
Fe_2O_3	3·80		7·41	6·18	3·75	9·73	12·62	14·46
FeO	33·43	30·00	23·35	19·93	21·75	24·48	21·98	22·89
MnO	0·45	0·25	·77	·75	0·15	1·17	0·63	
CaO	4·65	11·00	10·59	10·24	10·52	6·93	9·87	5·14
MgO	0·81	2·25	1·90	1·11	2·54	0·17	1·35	0·93
Na_2O	8·15		3·20	6·08	2·95	5·13	3·29	4·00
K_2O	1·66	trace	1·20	1·44	1·95	3·23	2·29	0·42
H_2O	0·15	0·75	1·30		·24	3·15	·35	·25
	100·80	98·25	99·61	99·64	99·91	99·64	99·61	100·00

I—Arfvedsonite, Kangerdluarsuk, Greenland. Lorenzen, Min. Mag., v, 50, 1882. II—Noralite, Nora, Westmanland, Sweden. Klaproth, Beitrage, v, 153, 1810. III—Hudsonite, Cornwall, N. Y. Analysis by J. L. Nelson and W. W. Daniells. IV—Barkevikite, Barkevik, Norway. Analysis by G. Flink, Brögger, Zeit. d. Kryst., xvi, 142, 1890. V—Barkevikite, Square Butte, Mont. Lindgren and Melville, this Journal, xlv, 292, 1890. VI—Amphibole, Beverly, Mass. F. E. Wright, Tschermak's Min. u. Petrog. Mitth., xix, 312, 1900. VII—Hastingsite, Dungannon, Ontario. Adams and Harrington, this Journal, ii, 213, 1896. VIII—Bergamaskite, Monte Altino, Bergamo, Italy. Lucchetti, Groth's Zeitschr., vi, 199.

These amphiboles are seen to have a low content of silica, and if the content of TiO_2 had been determined in each case, it is likely the similarity in amount of SiO_2 as well as TiO_2 would be still more apparent. Next in amount to silica is the iron, which prevails in the protoxide form; the alumina is abundant though variable; the lime is greatly in excess of magnesia; and the alkalies, especially soda, occur in considerable quantity. The amphibole noralite was analyzed by Klaproth in 1810 and the analysis should be taken with some reservation, for good methods for determining the mineral constituents, and especially the alkalies, had not at that time been devised. The noralite, however, seems well worthy our attention in comparison with the other amphiboles of this table. The hudsonite appears to be more nearly like VII, hastingsite, in composition than the others. Their optical properties, especially the inclination of the plane of extinction to the vertical axis, appear to be quite variable. So far as recorded, the angles of extinction are as follows: arfvedsonite, $c \wedge \dot{c}(3) = -14°$; hudsonite, $c \wedge \dot{c} = +9°$; barkevikite, Barkevik, $c \wedge \dot{c} = +12\frac{1}{2}°$; barkevikite, Square Butte, $c \wedge \dot{c} = +13°$; amphibole, Beverly, $c \wedge \dot{c} = +21$. So far as principal features of composition are concerned, all these amphiboles might well be placed in the same class with arfvedsonite, though retaining in each case their varietal names on account of slight differences in composition and in optical properties.

Geological and Natural History Survey of Wisconsin,
Madison, Wisconsin.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Crystallized Hydrogen Peroxide.* — It is announced by Wilhelm Städel, that, contrary to previous assertions, hydrogen peroxide crystallizes with ease and in a very distinct manner. Its melting point is about −2°. A preparation containing 95 to 96 per cent of hydrogen peroxide remained liquid in a freezing-mixture at −20°; but in a mixture of solid carbon dioxide and ether it solidified to a hard mass. It appeared to be necessary to cool the preparation to a temperature between −20 and −23° before it solidified. If a trace of the solid material is thrown into the liquid cooled to −8 or −10°, magnificent needle-shaped crystals immediately form, which are as clear and transparent as water, and which soon permeate the whole mass. By draining the mother-liquor from these crystals and allowing them to fuse, then repeating the crystallization, peroxide of hydrogen free from water is obtained.

A number of reactions were tried with the anhydrous substance: an extremely small quantity of platinum-black produces catalytic action accompanied by a violent explosion; powdered manganese dioxide, or a mixture of carbon and metallic magnesium with a trace of manganese dioxide, takes fire immediately when put in contact with the substance; finely-divided metallic iron is without action, but when a little powdered manganese dioxide is added the iron burns and throws off sparks; powdered lead is ignited in the same manner; a few drops of anhydrous hydrogen peroxide, when thrown upon wool or moist sponge, immediately bursts into flame; concentrated sulphuric acid can be mixed with it if this is done at a low temperature, but if the temperature is allowed to rise too high, oxygen very rich in ozone is given off.

It appears that the problem of preparing anhydrous hydrogen peroxide on a large scale has been solved by the process which has been described, while the pure product thus produced shows an unexpected degree of stability. A well-packed sample was carried on an ordinary truck for seven days over a distance of 50 or 60 kilometers without undergoing more than a slight change under these unfavorable circumstances.—*Zeitschr. angew. Chem.*, 1902, 642. H. L. W.

2. *Fumarole Gases from Mount Pelée.*—Moissan has analyzed samples of gas carefully collected by Lacroix from a fumarole of the Blanche River after the catastrophe of May 8th, 1902 and before the eruption of Aug. 30th of the same year. It is reported that pieces of lead placed in the mouth of the fumarole melted rapidly, while zinc remained solid, so that it is assumed that the temperature was about 400°. It is stated that the opening was in conglomerate, and that an abundance of sulphur and ammo-

nium chloride was deposited about it. Four separate samples gave nearly the same results as far as the chief constituents were concerned, and one of the samples more fully examined gave the following results:

Carbon dioxide	15·38
Oxygen	13·67
Nitrogen	54·94
Argon	·71
Carbon monoxide	1·60
Methane	5·46
Hydrogen	8·12

The gas as it was emitted was mixed with much steam. It contained also traces of hydrochloric acid and sulphur vapor, but hydrogen sulphide, acetylene and ethylene were absent and no helium was found. The gas is peculiar when compared with gases described from other volcanic eruptions, in containing a considerable quantity of the combustible gases, hydrogen, carbon monoxide and methane. Moissan calls attention to the poisonous nature of the gas, due to the carbon monoxide in it, and he suggests that many of the victims of the eruption may have died from breathing it. No comment is made in regard to the presence of large amounts of oxygen with combustible gases, but it seems incredible that such a mixture could have existed in the incandescent regions of the volcano, and hence it appears to be certain that the combustible gases, whatever their origin may have been, were mixed with atmospheric air at a comparatively low temperature.—*Comptes Rendus*, cxxxv, 1085. H. L. W.

3. *A New Reaction for Certain Oxidizing Agents.*—L. L. DE KONINCK has found that when one or two drops of nitric acid of sp. gr. 1·35–1·40 are added to a boiling solution of a manganese salt in fuming hydrochloric acid, the color of the liquid changes to a very dark green with a tinge of yellow, owing to the formation of manganese tetrachloride or some similar compound. The color is very stable while the acid is concentrated, but it disappears upon dilution. The test is made with a solution of $0{\cdot}001^{g}$ of manganous chloride in 1^{cc}. Besides nitric acid, nitrates, chlorates, hypochlorites, chromates, and lead dioxide give this reaction, while sodium bromate, potassium perchlorate, sodium peroxide, bromine, potassium persulphate, red lead and sodium nitrite do not give it. It is remarkable that sodium bromate and potassium nitrite do not give the reaction, and it is evident that they do not liberate chlorine when treated with hot, concentrated hydrochloric acid. The opposite behavior of lead dioxide and red lead is also very peculiar.—*Chem. Centralbl.*, 1902, ii, 14. H. L. W.

4. *Synthesis of Anhydrous Hydrosulphites.*—By the action of gaseous sulphur dioxide upon the metallic hydrides which have been recently described by him, MOISSAN has prepared the hydrosulphites of potassium, sodium, lithium, calcium, and strontium. The reaction in most cases is very energetic, so that it is neces-

sary to dilute the sulphur dioxide with hydrogen, or to allow it to act at low pressure upon the solid hydrides, in order to avoid decomposition by the heat produced and to obtain pure products. Moissan finds that the hydrosulphites correspond to the formula $M'_2S_2O_4$, and not to $M'_2HS_2O_4$, thereby apparently settling an uncertainty which has existed for a long time. The reaction which takes place in the case of the potassium salt is as follows:

$$2SO_2+2KH=K_2S_2O_4+H_2.$$

The reactions with the other hydrides are analogous to this.—*Bulletin*, xxix, 10. H. L. W.

5. *The Solubility of Boric Acid in Hydrochloric Acid Solutions.*—The statement made in a commonly used hand-book of inorganic chemistry, that boric acid is more soluble in hydrochloric acid than in water, has been found to be incorrect by W. Hertz. His results show that the solubility of boric acid rapidly decreases as the strength of the hydrochloric acid increases until the latter is about four times normal. At this point the solubility is only about one-third as great as in water. As the strength of the hydrochloric acid is then increased up to nine and one-half times normal, the solubility of the boric acid is practically constant. Since the ionic dissociation of boric acid is very slight, it appears that the usual explanation, based upon the decrease of ionization from the effect of the hydrogen ions of the hydrochloric acid, will not apply in this case.—*Zeitschr. anorg. Chem.*, xxxiii, 355. H. L. W.

6. *The Preparation of Pure Iron.*—Iron which was crystalline in structure and pure white in color, which dissolved slowly but completely in dilute sulphuric acid with evolution of odorless hydrogen, has been prepared by Skrabal. A platinum electrode was first coated with iron from a ferrous ammonium oxalate solution, then the electrode thus prepared was used as an anode, and the pure iron was deposited on a platinum cathode in a solution of ferrous sulphate acidified with sulphuric acid. A current of low tension (0·4 volt) was used.—*Berichte*, xxxv, 3404.

H. L. W.

7. *Beitraege zur Chemischen Physiologie;* herausgegeben von Franz Hofmeister. III Band, 1–8 parts. Braunschweig, Vieweg und Sohn, 1902.—The first eight parts of the third volume of Hofmeister's Beitraege bring fresh evidence of the increased attention which is being devoted to the chemical study of the albuminous bodies. It is impossible to review in this place the twenty papers presented; it must suffice to refer in particular to Friedmann's interesting studies of the sulphur-containing groups of the proteids, to the physiological studies on the proteolytic digestion products (Embden and Knoop, Zunz, Langstein), and to Czapek's extensive investigation of proteid synthesis by lower plant organisms. The application of modern physico-chemical methods to the solution of physiological problems is also further indicated in papers by Laquer and Sackur and by Pauli. L. B. M.

8. *Expansion of Melted Quartz.*—The new uses of melted quartz, or more exactly amorphous silica, make the determination of its physical properties of importance. Vessels made from amorphous silica have the remarkable property of acting like metals when subjected to heat. After being heated to a red heat they can be plunged into cold water without injury. L. HOLBORN and F. HENNING have measured the expansion coefficient of this substance and find it to be 0·00000054.—*Ann. der Physik.*, No. 2, 1903. J. T.

9. *Purification of Drinking Water by Ozone.*—The use of ozonized air for this purpose is attracting attention.

The East London Water Company has been carrying out trials at Lea Bridge with one method and appear to be fairly successful. Prof. VAN'T HOFF lately gave some details of the Vosmaer-Lebret process. The ozonizer in this process does not use glass and the silent discharge takes place between the walls of metallic tubes. An electromotive force of 10,000 volts is employed. A large portion of organic matter and of the colonies of bacteria were removed by the process.—*Nature*, Jan. 1, 1903. J. T.

10. *A disturbance-free Torsion Magnetometer.*—The present use of the earth for returns by the electric tramways makes the carefully perfected methods of Gaus and Weber almost useless. F. KOHLRAUSCH and L. HOLBORN describe a new instrument which overcomes many of the difficulties which have arisen in the use of old methods. A complete description of the instrument is given. The position of rest of the suspended portion remains for months with a change of barely one scale division; and the instrument is not affected by the sudden changes due to the electric roads in the neighborhood of the Reichanstalt.—*Ann. der Physik.*, No. 2, 1903. J. T.

11. *Fatal effect of Electric Currents of low Potential.*—It has been often maintained that a potential below a thousand volts is not dangerous to human life. Numerous casualties have shown the fallacy of this belief. The current strength is just as important a factor as the electromotive force. There is no question that a potential of 500 volts with a strength of current such as is employed on the third rail system in our cities is deadly, when good contacts are obtained. A fatal accident occurred at the Fulham public baths in England, on Dec. 28, 1902. Two bathers were killed by standing up in the bath and grasping an electric conductor which ran alongside the baths. The voltage was only 170. Very good contact was obtained.—*Nature*, Jan. 8, 1903. J. T.

12. *Velocity of X-Rays.*—Mon. M. R. BLONDLOT by an ingenious method has measured this velocity in air and finds it to be the velocity of light. The principle of his method consists in employing the well known property of the X-rays in facilitating the spark discharge. Electric waves along wires were produced and at definite distances it was found that the rays increased the amplitude of these waves. A consideration of wave lengths and

distances of the X-ray bulb gave the data for determination of the velocity of the rays. X-rays of different penetrating power were employed and the velocities of the rays were measured in paraffin, wax, beech wood, vaseline, oil, and essence of turpentine. The velocity was the same in all these media and was equal to the velocity of light in air.—*Comptes Rendus*, Oct. 27, Nov. 3–10, Dec. 29, 1902. J. T.

13. *Sound Waves and Electromagnetics.*—OLIVER HEAVYSIDE calls attention to the photographs of flying bullets taken, some years ago, by Professor Boys, and asks if there is anything analogous in electromagnetics to the mass of air which the photographs showed to be pushed in front of the bullet. Suppose that the electron is jerked away from an atom so strongly that its velocity exceeds that of light. Heavyside discusses the question from a mathematical point of view, and the conclusion apparently is that there are mathematical solutions which give color to the possibility of such a motion of the electron.—*Nature*, Jan. 1, 1903. J. T.

14. *The Physical Papers of Henry Augustus Rowland.* 697 pp., 6 pls. The Johns Hopkins Press, Baltimore.—A committee of the faculty of Johns Hopkins University has edited Professor Rowland's papers as a memorial of their colleague. The bibliography contains 72 titles and of these there are now reproduced: 4 Early Papers (written before 1874); 31 papers on Magnetism and Electricity; 4 papers on Heat; 16 papers on Light; 6 Addresses. A description of the Dividing Engines for ruling gratings is here published for the first time.

15. *Laboratory Manual of Physics;* by HENRY C. CHESTON, PHILIP R. DEAN and CHARLES E. TIMMERMAN. 128 pp. American Book Co.—Three instructors in the New York High School have produced a practical brief manual for elementary work in physics.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—The following publications have recently been received:

BULLETIN No. 196. Topographic Development of the Klamath Mountains; by J. S. DILLER. 66 pp., 13 pls., 7 figs.—The Klamath Mountain region has experienced a long and complicated series of changes beginning with the early Mesozoic. Mr. Diller traces sixteen different movements and erosion stages, beginning with an uplift at the close of the Eocene and ending with the recent Coos Bay subsidence.

BULLETIN No. 197. Origin of Certain Place Names in the United States; by HENRY GANNETT. 280 pp.—The origin of 10,000 names has been investigated and interesting facts regarding local history are brought to light.

BULLETIN No. 198. The Berea Grit Oil Sand in the Cadiz Quadrangle, Ohio; by W. T. GRISWOLD. 42 pp., 1 pl., 1 fig.—A detailed study of the Berea Grit adds proof to the anticlinal

theory of oil and gas accumulation. So direct is this evidence that a map has been constructed for the guidance of prospectors.

BULLETIN No. 199. Geology and Water Resources of the Snake River Plains of Idaho; by I. C. RUSSELL. 185 pp., 25 pls., 6 figs.—Southern Idaho is largely an untrodden field to geologists and Prof. Russell's preliminary report on the region is an important addition to geologic literature. The rocks surrounding the Snake River Plains are pre-Tertiary and consist of granite, rhyolite, quartzite and limestone. The Plain itself is made up of Tertiary and recent lacustral formations and lavas. That volcanic activity was contemporaneous with the existence of the lakes is shown by interbedded basalts, clays, sands and ashes. The Snake River lava is younger than the Columbia lava and the latest outpouring "occurred probably within historical times and are perhaps not over 100 or 150 years old." The lava came from a great number of inconspicuous craters on the plain and in the adjacent mountains and flowed for great distances. One continuous stream is 50 miles long, 1 to 3 miles wide and about 300 feet deep. In the arid climate of Idaho these recent flows have had little opportunity to weather and the details of crater and cone and stream as well as of the bombs and blistered surfaces are unusually well preserved. The illustrations and descriptions in the Bulletin make these facts clear. The drainage of this region exhibits some unusual features, perhaps the most remarkable of which is the abundance of large springs which pour out from the northern wall of Snake canyon between Shoshone Falls and Bliss. They flow steadily throughout the year and in August and September equal in volume the water in the river.

2. *Die Alpen in Eiszeitalter;* by ALBRECHT PENCK and EDUARD BRÜCKNER. Parts 3 and 4, pp. 225–432, with many charts and figures. (Leipzig, Tauchnitz.)—The parts already published of Penck and Brückner's study of the Alps indicate clearly that the completed work will be full and trustworthy. The field observations are abundant and thoroughly justify the inductions based upon them. Pages 225–396 present a continuation of the discussion of the eastern Alpine border (see this Journal xiv, 315), examples of cirques, over deepened valleys, hanging valleys, drumlins inside of moraines, etc. are shown to occur in orderly fashion, and abundant proof is presented for strong erosion by the ice mass. The glacial formations of the Rhine Valley are described and mapped (pp. 396–432).

3. *Lakes of Southeastern Wisconsin;* by N. M. FENNEMAN. 168 pp., 36 pls., 38 figs. Wisconsin Geol. and Nat. Hist. Survey, Bull. viii.—The educational work of the Wisconsin survey is worthy of the highest commendation, and the recently published volume on the physical geography of the lakes of the state will be of material aid to teachers and students. The book is well written and well illustrated. A set of hydrographic maps accompanies the volume.

4. *Publications of the Earthquake Investigation Committee in Foreign Languages*: No. 7, 54 pp., 4 figs; No. 9, 63 pp., 11 figs., 20 pls.; No. 10, 101 pp.; No. 11, 95 pp., 4 pls. Tokyo, 1902.—The great Mino-Owari and other recent destructive earthquakes have given Dr. Omari the data necessary for an exhaustive study of the "Deflection and Vibration of Railway Bridges" (No. 9). Dr. Omari also continues the unfinished work of the late Professor Sekiya, in a paper on "Macro-Seismic Measurements in Tokyo" (Nos. 10 and 11). Professor Tanakadate describes a "Vertical Motion Seismometer" (No. 7), and A. Imamura the "Seismic Triangulation in Tokyo."

5. *Phycologia Boreali-Americana.* Fasc. xix, xx; by F. S. Collins, W. A. Setchell and Isaac Holden.—This valuable work now includes twenty fascicles comprising one thousand numbers besides three fascicles of larger size with 75 numbers. This series of algæ exsiccatæ has never been surpassed in value by any similar work, and, if we consider not only the large number of species issued, the excellence of the specimens themselves and the remote and little explored regions from which in many cases they were obtained, but also the accuracy of the determinations and the detailed synonymy given on the labels, it is doubtful whether the series has ever been equalled. Fasc. xix is devoted to algæ from our Pacific coast as far north as Alaska, which were collected mainly by the botanists connected with the University of California. There is a short preface by Prof. Setchell describing the different regional divisions of the West coast with notes on the collectors of algæ on that coast. Besides such novelties as *Anatheca furcata* and *Fauchea Gardneri* and other characteristic western species, the series of species found also in other regions is important for a comparative study. Fasc. xx includes a new *Pithophora varia* Wittroch, *Rhizoclonium erectum* and *Dichothrix rupicola*, species recently described by Collins, and an interesting set of marine Cladophoræ and other green algæ. The Phycologia is indispensable to all who study the algæ of North America and the authors are to be congratulated on the extent and high quality of their undertaking.

W. G. F.

6. *Fungus Diseases of Stone-Fruit Trees in Australia and their Treatment;* by D. McAlpine. 165 pp., 54 pls. Melbourne, 1902.—Although the study of the plant-diseases of Australia is of comparatively recent date, a number of important contributions to the subject have appeared in the last few years, the latest being that of Prof. McAlpine of the Department of Agriculture of Victoria. The volume, which is very fully illustrated, a number of the plates being colored, brings out the unpleasant fact that, even in a country so remote from Europe and North America as Australia, there is no exemption from the diseases which infest older countries. The leaf-curl of peaches, the prune-rust, the shot-hole disease and numerous others are pests in Australia as well as with us. Nor, unfortunately, is Australia

without its own special fungi which are injurious to fruit trees, for Prof. McAlpine describes more than fifty new species of fungi of different orders which attack fruit trees, and their microscopic characters are well illustrated. The study of plant-diseases in Australia evidently offers a wide field for the mycologist and the pathologist. A chapter is devoted to the treatment of fungus diseases and, if the diseases are numerous, it is also true that, at the present day, much is known definitely in regard to their prevention. Prof. McAlpine's treatise is a valuable contribution to our knowledge of the comparative distribution of injurious fungi. W. G. F.

7. *Das Plankton des Norwegischen Nordmeeres;* by H. H. GRAN, Rept. Norwegian Fishery and Marine Investigations. II, No. 5, 222 pp., 1 pl., large 8°. Bergen, 1902.—This treatise by the well-known algologist, Dr. N. H. Gran, includes both animal and plant-forms of plankton organisms and is divided into two parts, a general and a special. The introduction gives a history of the study of plankton-organisms up to date and is followed by a chapter on the biology and distribution of selected species, of which the accounts of *Halosphæra viridis*, *Phæocystis Pouchettii* and of a number of pelagic Diatoms and especially of the Peridineæ, are of great interest to botanists. The second part of the volume, after an account of the different stations where collections were made, concludes with a systematic list of the species of both plants and animals included in the work, with notes on their distribution. Among them are several new species belonging to the genera Peridinium and Ceratium. W. G. F.

8. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Edited by J. STANLEY GARDINER. Vol. I, Part III, pp. 223–346, 33 figs., 4 pls.—The material collected by Mr. Gardiner in 1899 and 1900 is gradually being described (this Journal, xiii, 321; xiv, 74). Fifty known species of the Actinogonidiate Echinoderms are listed by Professor F. Jeffreys Bell. Many of them, as the *Ophioœthiops unicolor* Brock (1888), were hitherto known only by a single specimen. Professor Bell again urges the investigation of the question of the reproduction of the disc in certain ophiuroids. "It is clear that, if the gonads of an ophiuroid be set free by the separation of the disc, and if a new disc be formed and new gonads developed, the question of germplasm may be considered settled." In the short list of Orthoptera by Malcolm Burr, one species (*Liphoplus* sp.) is mentioned as possibly new. The third contribution, by L. A. Borradaile, on the Marine Crustaceans of the expedition, is an extended report on the Xanthidæ. Of the 89 species cited, 17 are described as new; for one, a new subgenus (*Platyozius*) is proposed, closely related to *Pseudozius* Dana. Two new genera, *Cœcopilumnus*, type *C. hirsutus* n. sp., and *Maldivia*, type *M. symbiotica* n. sp., are described, whose systematic relationship remains undetermined. Four known species belonging to the Atelecyclidæ and Hapalocarcinidæ are also given. Tate Regan

describes the Fishes taken within the lagoons and from fresh-water pools. Of the latter only one (*Barbus vittatus* Day) is a true fresh-water form. The Marine Turbellaria, by F. F. Laidlaw, contains a systematic list of 15 species, 13 of which are described as new, and many valuable anatomical notes are given with about a dozen text figures and two plates; the general figures being reproduced in colors. Some new and valuable deductions are given in conclusion and under "Natural History Notes" many interesting facts are mentioned, especially in regard to the collecting and preservation of material. K. J. B.

Mr. Gardiner continues his discussion of the formation of coral reefs and adds much that is new (pp. 313–346). He shows that the coral sand rock is formed by twice wetting and drying of the beach sand during the rise and fall of the tide. In the latter process the salts from the sea-water are deposited on the sand grains, many of which are redissolved by being covered by the tide, but carbonate and sulphate of calcium remain and fill the interstices of the sand, binding them together. The sulphate becomes replaced by less soluble carbonates and the rock ultimately formed of nearly pure carbonate of lime, the rock naturally being built from the surface downward. In nearly all cases the slope of the mass is that of the beach and becomes of great density and hardness as it is more and more indurated with carbonate of lime. From the study of such masses off any island the former extent and contour of the land may be deduced with considerable certainty. "The erosion of land in the Maldives, the formation of flats at about the low tide level by washing away of the land and hollowing out of such flats to form first pools, then velu or definite lagoons, may absolutely be traced."

In regard to the formation of lagoons Mr. Gardiner says: "In conclusion, it is a fair deduction that the increase both in depth and extent in the lagoons of the Maldive atolls is mainly due to solution, an important additional factor being the outwash of fine matter by the tidal and oceanic currents. It is obvious, though, that there are two nicely balanced sets of conditions, causing the filling in or increase in size of any lagoon."

The bathymetrical limits of various species of reef-building corals has been determined. "Darwin in placing the extreme depth of flourishing banks of surface-red corals at 25 fathoms was entirely correct. The specimens of these corals procured from beyond this depth show clearly in their growth that the increased depth is deleterious to them. At the same time the presence of a series of other genera of corals, which evidently flourish just beyond where the surface forms cease to exist, although with a considerable range in depth, is for the first time clearly demonstrated."

Mr. Gardiner had unusually favorable opportunities for studying the rate of growth of reefs and reaches a conclusion widely different from Dana's, who considered five feet in 1000 years an average. "Considering all the various factors, and particularly

remembering the necessarily slower growth at the initiation of a reef and as it approaches close to the surface, it yet seems to me to be probable that an oceanic shoal at a depth of 25 fathoms might well in 1000 years, or even less, be covered with a perfect surface reef, built up by nullipores and reef corals. Should these deductions be, as I believe, fairly accurate, a natural explanation is at once afforded of the rarity of submerged banks of all sorts in coral-reef areas as compared with surface atolls and reefs."

III. Miscellaneous Scientific Intelligence.

1. *Report of the Secretary of the Smithsonian Institution for the Year ending June 30, 1902.*—In his annual report Professor Langley gives a summary of the work done by the Smithsonian Institution in its several fields of activity. The appendixes contain detailed descriptions regarding the National Museum, the Bureau of Ethnology, the National Zoölogical Park, the Astrophysical Observatory, etc. The National Museum now contains five and a half million specimens and a new building is urgently needed. The Bureau of Ethnology is preparing a dictionary of Indian tribes as a preliminary step toward the publication of a complete encyclopedia on that subject. In the field work special attention was devoted to the study of aboriginal building irrigation and food sources. The number of libraries and individuals who are participants in the Exchange Service is now 38,200 in 154 countries. During the past year the researches carried on by the Astrophysical Observatory have mainly been concerned with determining the amount and nature of the absorption of solar radiation in the earth's atmosphere and in the solar envelope. These researches are preliminary to and form an essential part of the measurement of the total radiation of the sun. The bolometer has been perfected to measure less than one-hundred-millionths of a degree and "this almost infinitesimal amount is distinguished with readiness and precision." A successful method of overcoming the effects of "boiling" in a telescopic image is announced. (See this Journal, xv, 89.)

Obituary.

Professor Estevan Antonio Fuertes, head of the College of Civil Engineering at Cornell University, died January 23 at the age of sixty-four.

Dr. Charles J. Bell, professor of chemistry in the University of Minnesota, died on January 4, aged forty-eight years.

Dr. Antonio d'Achiardi, professor of mineralogy and geology at the University of Pisa, has died recently at the age of sixty-three.

Sir George Gabriel Stokes, the eminent mathematician, died on February 1, in his eighty-fourth year.